SURGERY OF MODERN WARFARE

Aphorisms for the War Surgeon

"Splint them where they lie."—Sir Anthony Bowlby, 1916

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"Shock from severe wounds and hæmorrhage always must take precedence of everything else."—W. W. Keen, 1917

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"It is absolutely necessary for a surgeon to search the wounds himself which were not drest by him at first, in order to discover their nature and know their extent."—A. Belloste, 1701

* * * * * *

"Doubt as to the condition of the wound should incline one to pessimism rather than to mistaken optimism."—W. H. Ogilvie on Primary Wound Excision, 1940

* * * * * *

"In the Armado Navall of Dunkirk, where we Chirurgeons were oft employed in this kind of work, we after every Fight went together visiting one another's wounded men. It was thought amongst us a great shame, if anything of this work of extraction were then to be done, for after the first and second day the Wound proveth tumefied, also the neighbouring parts are inflamed and so changed in their temper, that they conceal from your sight both the Bullet and his companions, so that the place they are couched in can hardly be known, or being discovered, you cannot without hazard of your patient, or great trouble of the Part, make Extraction of them."—R. Wiseman, 1676

"*Besides its reference to Dunkirk, this quotation has more than a topical interest. Wiseman enunciates an underlying surgical principle concerning wounds coming under treatment after a period of delay—a delay which even under modern conditions still prevails frequently.*"—Seymour Barling, 1940

* * * * * *

"War surgeons should try to emulate the dexterity of their ancestors, who had to perform amputations at lightning speed."—J. Berry Haycraft, 1941

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"Surgery will only prescribe the amputation of limbs in extreme cases where this sacrifice is indispensable for the preservation of life."—Baron Percy, 1792

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"Wounds in the joints are always dangerous."—John Ranby, 1781

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"It is safer to look and see than to wait and see."—Sir Cuthbert Wallace on Abdominal Wounds, 1916

* * * * * *

"It is highly desirable that anyone engaged in war surgery should keep his ideas fluid and so be ready to abandon methods which prove unsatisfactory in favour of others which, at first, may appear revolutionary and even not free from inherent danger."—H. H. Sampson, 1940

SURGERY
OF
MODERN WARFARE

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COMPILED BY SEVENTY TWO CONTRIBUTORS

VOLUME I

With 375 Illustrations

Many in Colour

Second Edition

(*Complete in Two Volumes*)

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PREFACE TO THE SECOND EDITION

WHILE what I believe to be a number of improvements have been effected, the principal innovation of the present edition is that it is being issued in two volumes; such an arrangement, it was considered, would be more convenient for the reader both for study and reference.

As the war has lengthened and spread, surgical experience has progressed *pari passu*. Consequently in certain directions it has been possible to be more dogmatic than was the case in the first edition.

My task has been greatly lightened by the enthusiasm of the contributors and the many helpful suggestions received from Professor Ernest Finch, Lieut.-Col. John Bruce, Messrs. Norman M. Matheson, Murray T. Greig, John Boyes and Walter J. Cawkwell, who have also undertaken the reading of the proofs.

My grateful thanks are also due to Mr. W. J. Bishop, of the Royal Society of Medicine, for unfailing help with the current literature, and to Mr. T. J. Shields, the librarian of the British Medical Association, for preparing the index.

The Publishers and Printers, whom I know have worked under trying conditions with depleted personnel, obviously deserve our admiration for the quality of the production.

HAMILTON BAILEY

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May 1942

PREFACE TO THE FIRST EDITION

"SURGERY of Modern Warfare" has been written by a team which can claim to represent British Surgery. By this is meant that the members belong neither to a particular school nor are they drawn from any one medical service. Reflected in its pages is teaching from London, the Provinces, Scotland, Wales and Ireland, and experience culled from the Navy, Army, Air Force and Emergency Medical Service.

Some of the contributors base their views on observations made during the present conflict; others record ripe experience amassed during the eventful years 1914-18; not a few are able to contrast and compare the surgery of both campaigns.

So it comes about that into this surgical cauldron have been poured the fruits of much experience and ingredients which should be palatable to the war surgeon. In order to aid quick assimilation at a time when close study is difficult, the principles enunciated have been illustrated freely. Miss McLarty's artistic presentation of the operative procedures deserves special mention, and to Messrs John Wright & Sons I am indebted for permission to use several pictures from the *British Journal of Surgery*.

No effort has been spared to make the work a *vade-mecum* in whatever sphere of surgical activity the reader may find himself. The way in which the contributors responded to the call, and the tolerance, particularly of my seniors, in allowing me to cut and alter their text, fills me with gratitude.

There are sure to be criticisms of the book, but the manner of its production is beyond reproach. For this, which is the reflection of efficiency on all matters relating to publishing, I accord my sincere thanks to Messrs E. & S. Livingstone. Mr Charles Macmillan, their manager, has been a constant inspiration to me in overcoming difficulties, some of which at the time seemed insurmountable.

Mr John Boyes, Major John Bruce and Mr N. M. Matheson have rendered yeoman service in proof-reading; they have never faltered in carrying out this onerous task meticulously and promptly.

Lastly, I am only too conscious that the compilation of the book could not have been completed in anything like the time if, as in all my literary labours, my wife had not helped me at every turn.

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149 Harley Street, W. 1,
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WOUNDS: GENERAL CONSIDERATIONS

CHAPTER I

PROJECTILES AND OTHER ENGINES OF DESTRUCTION

An account of war wounds is hardly comprehensible without an elementary knowledge of the agents which cause them

Projectiles may be divided into three varieties —

1 Rifle, revolver and machine-gun bullets
2 Shells from artillery and trench mortars
3 Bombs and grenades

Methods of inflicting wounds change as rapidly as methods of treatment An analysis of wounds of the 1914 18 war showed that they were inflicted as follows —

Bullets, rifle and machine-gun	39·61 per cent.
Shells from artillery and trench mortars	58·21 „
Bombs and grenades	2·18 „

Statistics are not available for the present war but it is obvious that the percentage of wounds from aerial bombs has increased enormously

A travelling missile has a definite and fixed amount of kinetic energy represented by the formula $\frac{1}{2}mv^2$ The kinetic energy of missiles in the present conflict varies more than has obtained in previous wars A missile leaving a stationary gun possesses a certain velocity Should the gun itself be moving as when fired from aeroplanes and motorized units the velocity of the missile with its consequent capacity for destruction is increased

BULLETS

Under this heading may be included the bullets fired from rifles machine guns and revolvers for the construction of the missiles projected from these weapons is roughly the same Modern bullets are of two types—those composed of a hardened metal covering and a soft core of lead *e g* British and German and those formed of a solid copper alloy *e.g* French

Shape—In order to increase its velocity the old cylindrico-conical bullet has been replaced by one more pointed (Fig 1) for this type offers less resistance and consequently has a greater range

Fig 1

German standard rifle bullet.

Range of a modern German rifle bullet is about $1\frac{3}{4}$ miles From some of the latest weapons the range of the missile is increased to over $2\frac{1}{2}$ miles

Trajectory—The curve of the trajectory is due primarily to the force of gravity which exerts a downward pull on the projectile from the instant that it leaves the rifle The bullet having the greatest speed will have the flattest trajectory

Velocity—The muzzle velocity of the German rifle bullet is 2,800 ft per second Owing to air resistance this is reduced rapidly, until at the end of about 600 yds it approaches the velocity of sound—1,100 ft per second

Motion—As well as moving along the line of its trajectory, a bullet has two other movements imparted to it there is the motion of rotation on its axis caused by the rifling of the gun, and there is the motion of oscillation—that is to say, a movement that places it crosswise to its course, or even causes it to travel base foremost When a bullet traverses a substance of greater density than air, it tends to turn over the greater the velocity the more quickly will it turn So it comes about that it is the oscillatory motion which is of particular importance to the surgeon, it is usually spoken of as wobble

Wobble—The terrific air resistance at the commencement of its flight causes the bullet to wobble, so that any wound inflicted within 600 yds shows an explosive effect after this distance when its speed is reduced to that of sound, air resistance is diminished and the wobble disappears The bullet, now flying true, drills a clean hole, providing its velocity is not reduced appreciably, as might be the case if it strikes compact bone

Clean drills by a bullet give little trouble to the surgeon They formed the majority of wounds in the Boer War, and were responsible for the conservative treatment of war wounds which was so disastrous when applied during the war of 1914 18

Towards the end of their flight bullets again wobble Spent bullets are easily deflected from their path, they lodge in the tissues and are often found base first

Ricochets and deformed bullets—When a bullet enters the body it either enters it in the same shape as when it left the rifle, or, owing to ricochet it is liable to become deformed Again the component parts may become partly disintegrated, this occurs notably with the dum-dum

Dum-dum bullets—The destructive effect of a bullet is further increased by filing off its point (Fig 2), cutting grooves across its tip or reversing the bullet in its casing These dastardly practices give rise to the so-called mushroom effect when the bullet meets with resistance The mutilation caused by dum-dum bullets is notorious

Fig 2

German dum dum bullet

Revolver bullets—The German Luger automatic has a muzzle velocity of approximately 1,000 ft per second and the Mauser 7 63 mm automatic a velocity of 1,380 ft per second The Thompson sub-machine gun, so much in evidence in this war and generally referred to as the "Tommy-gun," also possesses an initial velocity of about 1 000 ft per second

PROJECTILES FIRED BY ARTILLERY AND TRENCH MORTARS

The projectile usually fired from such weapons is the high explosive shell Not infrequently the term "shrapnel" is used wrongly in this connection, this name rightly belongs to a special form of shell which on bursting delivers a varying number of round lead bullets approximately ½ in. in diameter.

High explosive shells have a thick iron casing enclosing a quantity of

Fig. 3.
Fragments from an 18 pounder high explosive shell.

violently explosive trinitro toluene. Bursting is brought about by means of a detonator which comes into action by impact. The fragments produced by the explosion vary enormously in size (Fig. 3)—from a millet seed to a

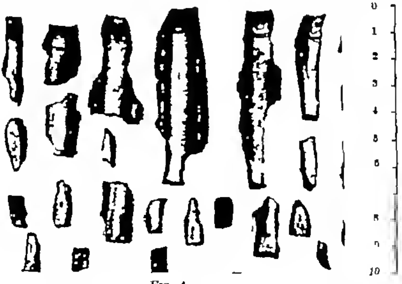

Fig. 4.
Fragments from a 12 pounder high explosive shell.

jagged mass of iron many pounds in weight. A chunk of iron such as this is capable of tearing off a limb or of crushing *it to pulp*.

Because of the irregular shape of these fragments, their mass and their number (Fig. 4), the wounds inflicted by shell fire are the worst that are seen in warfare. Not only do they produce great destruction of tissue but they carry in portions of clothing and equipment, thereby increasing the likelihood of severe sepsis

In order to give an indication of the number of fragments produced by the bursting of a high explosive shell, the following table from Lagarde's work on Gunshot Injuries is instructive —

Guns	Extreme Range	Weight of Shell	Approximate Number of Fragments
	Yds	Lbs	
3 in Field Gun	6,500		
and Mountain Howitzer	5,600	15	600
3 8 in Gun	7,300		
and Howitzer	6,200	30	800
4 7-in Gun	8,000		
and Howitzer	6,640	60	1,000
6 in Howitzer	6,704	120	1 500

Shrapnel shells consist of steel cylinders containing a varying number of round lead balls (Fig 5) The bursting charge is in the base and is exploded by means of a time fuse fixed to the head of the shell At the moment of bursting the balls are driven outwards in the form of a cone travelling at the velocity of 300 ft per second To this must be added the movement of the shell giving a total initial velocity of 1,700 ft per second Shrapnel is highly effective against massed troops in the open, but has little result when men are under cover The smooth balls cause far less damage than the high explosive shell fragments, although the nose-cap, which itself acts as a projectile, may inflict deadly wounds

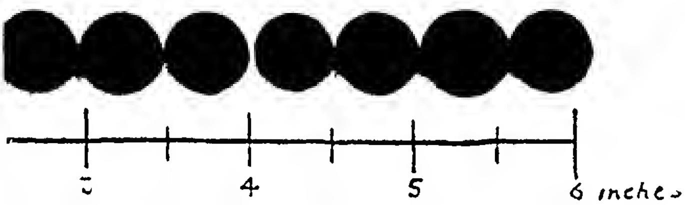

Fig 5
Shrapnel balls

GRENADES AND BOMBS

Grenades are all essentially the same although their method of projection may differ, being thrown either by hand (Fig 6) or fired from a rifle The casing is made of iron, often partially subdivided into segments $\frac{1}{2}$ in square, so as to ensure fragmentation The thickness may vary from $\frac{1}{2}$ to $\frac{1}{8}$ in , and the size of the fragments be anything from a pin's head up to a lump of metal weighing as much as an ounce Some of the German bombs used in the 1914-18 war contained jagged bits of loose iron nails All forms of bomb, grenade and shell scatter stones

Fig 6
Hand grenade

and earth which themselves become projectiles and add to the severity of the wound

Aerial bombs and torpedoes—A high explosive shell requires a strong

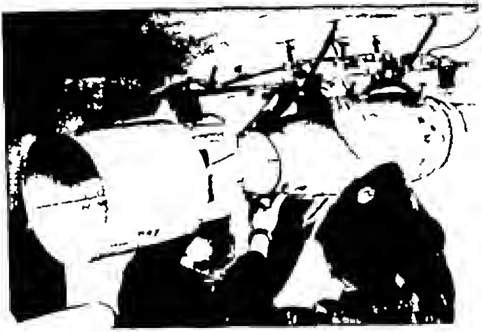

Fig 7
Royal Air Force bomb in position.

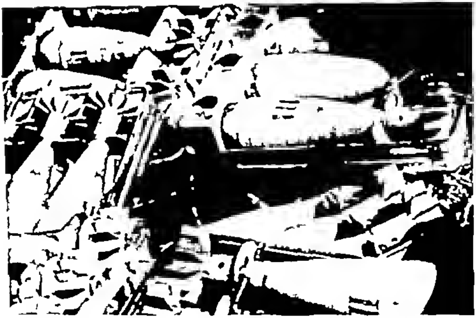

Fig 8
German aerial bombs captured in Russia.

casing in order that it may withstand the strain to which it is subjected on being fired from the gun A bomb dropped from an aeroplane (Fig 7) is free from such a strain and therefore can have thin walls German high explosive bombs (Fig 8) are composed of about 90 per cent of explosive material and

10 per cent spongy casing of aluminium alloy They are therefore comparatively light for transit by air, and they kill more by terrific blast than by wounding The thin-walled casing breaks into fragments varying in size from a thumb-nail to a pin's head These fragments travel at terrific speed At 50 ft they have a velocity of as much as 5,000 ft per second, and they have imparted to them a rotary movement Furthermore although not incendiary in the technical sense they begin their flight at an incandescent temperature Such missiles travelling at this enormous velocity produce devastating effects in soft media Whilst on the surface there appears only a trifling wound, beneath the skin there is a widespread destruction that has to be seen to be believed This destruction is the result of the momentum imparted to the soft medium by the high-velocity projectile, so that there is produced an effect similar to that of an internal explosion

Fig 9
"Molotoff bread basket"

Thus among the special points arising from aerial bomb warfare are the following Because the wounds are multiple and because even what appears to be an insignificant surface lesion may be associated with serious underlying injury a very careful preliminary examination of the whole patient is necessary before any treatment is undertaken Nothing can be more disastrous to good work than to find that after having dealt with what had appeared to be the chief injury in the way of a compound fracture of a limb, the patient has a minute penetrating wound of the abdominal wall with an underlying lesion of an abdominal viscus

Incendiary and oil bombs—Oil bombs (Fig 9) are filled with crude petroleum, and the action of the contents of these bombs on living tissues is often appalling Uncovered parts receive extensive, deep, third-degree burns, and the chemical erosion is similar to that found in alkali injuries Extensive œdema, with the face swollen to two or three times its natural size, is characteristic, and the gases produce lesions resembling corrosive bronchitis

BAYONETS

Bayonets (Fig 10) are used comparatively infrequently In the 1914-18 war, wounds from bayonets comprised under 5 per cent of all wounds, many of these were accidental and due to a soldier impaling himself on his own bayonet while clambering into a trench in the dark

TRENCH CLUBS (SYN KNOBKERRIES)

Trench clubs (Fig 11) are used in hand-to-hand fighting, and often produce fractures of the skull and other head injuries They are very lethal weapons

FIG 10
German saw back sword bayonet

FIG 11
Knobkerries.

FLAME PROJECTORS (FLAMMENWERFER) AND FLAME-THROWING TANKS

These are among the new German engines of destruction The flammenwerfer consists of a reservoir containing fluid fuel and of such a size that it can be strapped on the back of an infantryman Through the attached hose the ignited fluid is projected The man detailed for this ghastly task is provided with considerable protection in the shape of asbestos clothing and a shield for the eyes The flame-throwing tank is a large-scale elaboration of the above unit Terrible burns caused by petrol and other oils exploding contribute a large toll of casualties in all the fighting services

MINES

Mines can be either marine (Fig 12) or terrestrial Terrestrial mines consist of charges of 50 to 80 lbs of aminol or gelignite which is inserted into the ground through a narrow hole to a depth of 7 or 8 ft The mine can be fired by various methods such as electrical contact or a time fuse Eighty pounds of explosives will blow a crater 25 ft in diameter and 8 ft deep The débris thrown up by the explosion forms the projectiles

Mines of both varieties, by their terrific explosion, are responsible for another type of injury—internal damage without external wound For

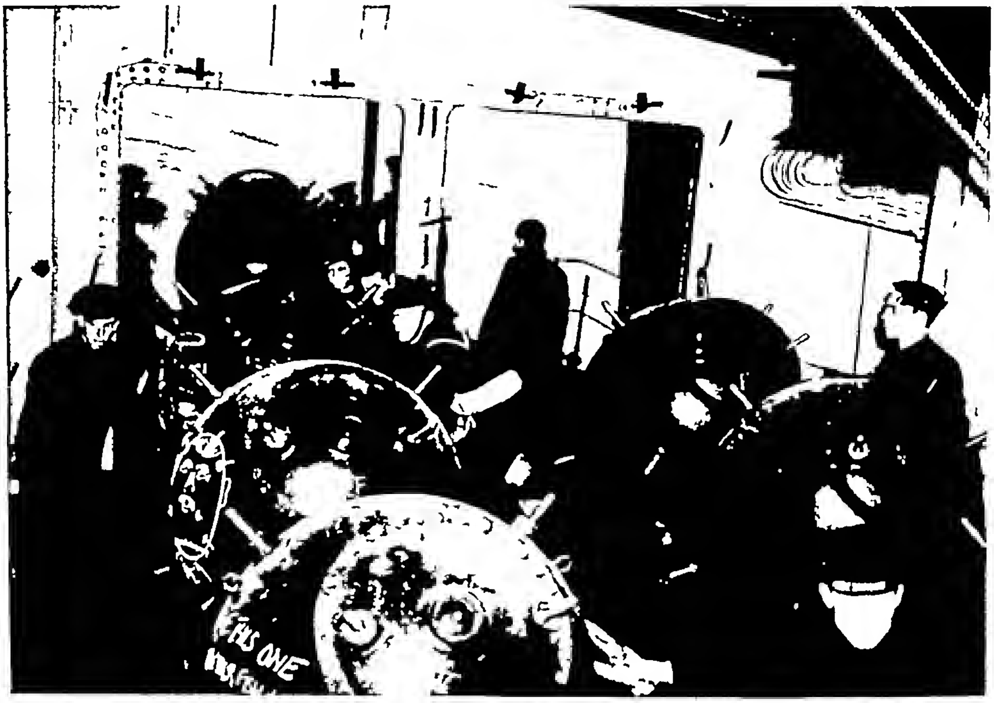

FIG 12
Laying marine mines

instance Rear-Admiral Gordon-Taylor, in Chapter XLI, describes sub-parietal rupture of the colon without breach of the skin, received by ship-wrecked men in the water from detonation of mines or depth charges

PERSONAL PROTECTION AGAINST THESE WEAPONS

In armour protection lies the counter-measure of the modern engines of destruction It would appear that protection is possible against the small high-velocity bomb fragment As pointed out in Bashford Dean's very complete work on armour protection, all sorts of materials have been suggested, for instance, various forms of cloth have been tried S Zuckerman proved conclusively that when an animal's body was clothed with thick layers of rubber, little damage was sustained by the effects of blast Many plastics, such as bakelite and compressed fibre have a high stopping power So far nothing has been invented to compare in this respect with manganese and chromium steel

FIG 13
Seriously damaged helmet of a patient with but a slightly scored cranium
(*British Journal of Surgery*)

Replete in his armour many a knight must have reflected with pity and admiration on his forebears who braved sword and arrow with a hand shield So, perchance, a future generation, with their eyes necks, chests and abdomens protected adequately, will view with compassion the men and women of our day who face exploding bombs and shells with, at the most, a metal hat designed to protect their vertex (Fig 13)

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CHAPTER II

CLASSIFICATION OF WAR WOUNDS

A STATISTICAL survey of wounds could be of immense value to the executive branches of the fighting services Representatives of the Royal Naval Medical Service the Royal Army Medical Corps and the Royal Air Force Medical Service, with special knowledge of massed statistics of wounds, should guide the efforts of those responsible for armouring ships, aeroplanes, tanks, lorries etc In turn it should be incumbent upon all surgeons to be in a position to correlate their observations in order to supply these Service surgical statisticians with reliable data

Fig 14

Multiple wounds caused by bomb explosion (*British Journal of Surgery*)

Multiplicity of wounds—This war differs from its predecessors in the extensive use of aerial weapons One of the worst features of modern war wounds is their multiplicity The wounds produced by any kind of bomb (Fig 14) are notorious in this respect Grave shock and extensive tissue disruption with early virulent infection characterize these wounds, but this is not all Added to these is an element of concussion or even the phenomena generally known as blast ' (see Chapter IV)

As the result of the important part played by the aeroplane in modern warfare fighting men are as much exposed to the enemy *above* them as they were to the enemy *in front of them* Because the aerial bomb breaks into innumerable fragments and is as likely to burst behind as in front of the victim multiple wounds scattered over widespread areas of the body are exceedingly common One description that has been given of this present conflict is that it is the war of the crouching man On hearing the noise of an enemy aeroplane overhead a person instinctively crouches or falls to the ground so that the back is even more exposed to injury than the front of the body

Some principles in assessing the tissue damage caused by a missile—A CAREFUL HISTORY IS IMPORTANT—It is very helpful to know the nature of the missile whether it is smooth such as a machine-gun bullet or shrapnel ball or rough such as a splinter of bomb or shell The smooth missile tends to take the line of least resistance and to follow fascial planes whereas an irregular missile shows no such predilection One instance of many can be quoted of a soldier wounded in the right shoulder A shrapnel ball was removed from beneath the skin of his right groin No incapacity resulted Evidently the smooth missile had followed the fascial planes Over and over again the patient will indicate that the maximal pain is experienced in a certain area at a distance from the wound Careful palpation of such an area will often reveal the induration of the missile which can be detected even at a depth of 2½ in below the skin surface

FIG 15

Transverse section of tibia immediately below a shrapnel ball, showing area of bruising (*British Journal of Surgery*)

When possible inquire as to what position the patient was in when the wound was received whether sitting lying flat or kneeling whether walking or running This is especially important in regard to penetrating wounds of a joint and in particular the knee joint for foreign bodies are more easily extracted when the joint is flexed or extended to a greater degree than when the missile entered it

CALCULATING THE EXTENT OF THE INTERNAL DAMAGE—Should the greater part of a missile's kinetic energy be expended in damaging superficial structures little remains to produce deep damage When this kinetic energy is expended on the surface the deeper damage depends upon the resistance of the structures encountered Should the missile impinge upon soft parts only a perforating through-and through wound is likely to result On the other hand if it impinges upon bone (Fig 15) its kinetic energy may suddenly be reduced to zero with the result that what might have proved a perforation of soft parts only becomes a site of excessive tissue destruction So it comes about that the more extensive the superficial injury the less the probability of damage to deep structures If the outward and visible damage is

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As the result of the important part played by the aeroplane in modern warfare, fighting men are as much exposed to the enemy *above* them as they vary but on the whole perforating wounds have a better prognosis than penetrating wounds Perforating wounds are most often the result of missiles fired at close range and may comprise

(a) A small hole of entry and a small hole of exit
(b) A small hole of entry and a large hole of exit
(c) A large hole of entry and a large hole of exit
(d) Gutter wounds

(a) **A small hole of entry and a small hole of exit** are wounds which for the most part are caused by rifle and machine gun bullets (Figs 16 and 17)

Fig 16

Fig 17

Fig 16—Perforating wound caused by a machine-gun bullet fired from an aeroplane on 27th May 1940 The wound of exit is shown in the mirror Fig 17 shows the radiograph of this case

The amount of damage varies Thus a bullet may traverse a limb without damaging important structures both entry and exit wounds healing and leaving no incapacity (tunnel wound) Again a similar bullet may traverse the limb in a direction almost identical with the preceding and after an hour or two the member will be acutely swollen and tender denoting damage to an artery of considerable size The exit and entrance wounds give the observer some idea what damage to expect since the course of the missile is known approximately Surface anatomy though useful is not always a true guide to damage done because many cases have been seen where the track judged by the entrance and exit wounds passed right across the course of such structures as the femoral artery the sciatic nerve the brachial artery etc without damaging them Here again there are two comparatively inconspicuous, the important question is, "Is there an exit wound ?" The greatest internal damage is to be anticipated in cases with a comparatively small wound of entrance and no wound of exit These are termed "penetrating or lodging wounds"

Fragments of high explosives, owing to their ragged nature, be they ever so small inflict greater damage upon soft tissues than do machine-gun bullets or shrapnel balls Furthermore, these irregular fragments almost invariably carry in foreign matter, such as pieces of clothing, a state of affairs favouring early and virulent infection In addition to pieces of clothing, a missile may carry into the tissues articles carried in the pockets Thus coins, pencils, buttons, pieces of string, and in one instance a large piece of a miniature New Testament have been extracted from wounds in the upper thigh On the other hand, a cigarette case carried in the breast pocket of a tunic has on more than one occasion either stopped or deflected the course of a missile which might otherwise have proved fatal

THE SIZE OF THE WOUND OF ENTRY IS NO GUIDE TO THE SIZE OF MISSILE—Skin is an elastic structure and in most cases the skin wound is smaller than the missile which caused it In wounds of the chest the skin wound is not an indication of the point of entry into the thoracic cavity, as the chest wall is a movable structure The skin wound is often at a higher or lower level than the actual entrance into the pleural cavity The track of entry is thus valve-like, and such wounds can produce the most extreme degree of surgical emphysema Wounds of entry in the skin and in the deep fascia or joint capsule are only approximately at the same level if the body was at rest at the time of wounding

It is important to realize that in gunshot wounds laceration is not always confined to the wound itself, it can involve tissues at a considerable distance For instance, it is not uncommon for a bone to be fractured, not at the site of impact but at a point some distance away

NON-PENETRATING WOUNDS

Non penetrating wounds can be divided into two varieties —

1 **Superficial contusions**—War contusions should never be treated lightly, particularly those involving the head and trunk Often what appears at first sight to be a trivial contusion is associated with grave internal complications

2 **Deep contusions** are mainly the outcome of severe crushes brought about by collapsing masonry

PENETRATING (SYN. LODGING) WOUNDS

Penetrating wounds form a large and important fraction of the total wounds that reach the surgeon *Penetrating wounds have a wound of entry only* This wound may vary from an exceedingly small puncture, which in some cases is scarcely visible, to a wound of considerable dimensions

It is in penetrating wounds that the importance of early X-ray examination and localization of foreign bodies reaches its zenith

PERFORATING (SYN TRAVERSING) WOUNDS

Perforating wounds entail a wound of entry and a wound of exit They possess an advantage over penetrating wounds in that the missile has emerged and no longer remains in the body The actual damage to tissue

Tunnel wounds in the neighbourhood of large arteries are the commonest cause of traumatic aneurysm. Swollen thighs, the result of hæmorrhage if kept at rest and watched carefully slowly resume their normal size providing there is a good circulation in the foot When the swelling and bruising subside a pulsating mass with a bruit over it makes its appearance This happened in quite a number of cases, not only in the thigh but in the neck and elsewhere

Tunnel wounds of the forearm and lower leg should, if possible be left alone providing the circulation in the hand or foot is good. These wounds, if opened up, often give rise to hæmorrhage which is difficult to control

Tunnel wounds involving the abdomen or thorax may give rise to insignificant symptoms though from surface anatomy it would appear that serious damage has occurred; more often such wounds cause perforations in the case of hollow viscera, and serious damage to solid viscera and mesentery

Tunnel wounds of joints—It frequently happens that there is a valve-like perforation of the capsule and this is of value both in preventing escape of synovial fluid and blocking the route to infection For this reason small tunnel wounds of joints often remain sterile

Tunnel wounds involving bone—Simple perforation sometimes occurs, this being seen most frequently in the epiphyses of long bones A clean perforation of bone is, however comparatively rare

Tunnel wounds about the spine may involve the spinal cord or large intra-abdominal or intrathoracic vessels. Death in these cases is rapid and painless, and many cases were seen during active fighting

(*b*) **A small hole of entry and a large hole of exit**—This type is almost invariably the result of a missile fired at close quarters striking bone The lead in the bullet is flattened out and continues its course together probably with fragments of bone pushed before it The result is a large lacerated wound of exit (Fig 18) The same result occurs to an even greater degree when the missile is a piece of shell

Perforating wounds of the head, and often of the thorax come under this class. In the case of the skull the missile traverses the bony cranium twice The exit wound is large and a quantity of brain matter is usually protruding Few such cases reach surgical aid, and even if they do so recovery is extremely rare Wounds of the thorax belonging to this class are again usually fatal; ghastly wounds of exit are produced There are a few examples where large exit wounds of the thorax have been plugged with an ordinary towel and have reached surgical aid In the case of the abdomen it is not uncommon to see omentum and intestine protruding from the exit wound. Curiously this type of abdominal wound is often conspicuous by the absence of shock A number of men so wounded have walked from where they were hit to the regimental aid post. So long as there is no gross concealed damage to viscera or the mesentery the prognosis is good.

(c) **A large hole of entry and a large hole of exit** is usually the result of a direct hit with a piece of shell of considerable size or a ricochet bullet The wounds are connected by a ragged and torn track overhung by a bridge of tissue consisting of skin and perhaps some of the deeper structures This bridge which may or may not contain important structures is usually in a bruised and battered condition consequently it is exceedingly prone to become gangrenous Wounds belonging to this class are always extremely serious and early virulent infection is inevitable because of the disruptive effect To save life and limb immediate and thorough treatment is imperative Of course many of the victims of this type of injury never reach surgical aid Fortunately there seems to be little or no pain associated with these ghastly wounds

(d) **Gutter wounds**—As the name implies the missile ploughs a furrow in the tissues between its entrance and exit (Fig 19)

FIG. 19

Gutter wound involving the biceps. (*British Journal of Surgery*) important considerations upon which the wounded man can usually give information —

1 Was he lying down or standing still ?
2 Was he running or walking when wounded ?

If he was lying down or standing still the entrance and exit wounds give a fairly accurate estimate of the course of the missile If he was running or walking when wounded, the wound in the skin does not usually correspond

Fig 18
Explosive effect on the exit wound caused by a rifle bullet fired at close range
The inset illustrates the wound of entry (*British Journal of Surgery*)

in position with the wound in the deep fascia and muscles at either the site of entry or exit This disparity may be as much as an inch it is usually somewhat less The reason for it is obvious because when the body is in motion the skin is stretched in some parts and relaxed in others The same phenomenon occurs, to a more marked degree if the bullet strikes the part obliquely

TUNNEL (SYN SETON) WOUNDS

Tunnel, or seton, wounds are those which, while coming under category (*a*) because they possess a small wound of entrance and a small wound of exit, are set apart because, like a railway tunnel, they are of the same calibre throughout They are, on the whole, comparatively innocuous

There is an outpouring of lymph into the spaces formed in the disrupted tissues and the part swells (Fig 21) In the case of a limb tension beneath the deep fascia may become so great as to jeopardize the circulation Seymour Barling in Chapter XI shows that during disruption and reactionary œdema the tissues are contaminated but not yet visibly infected

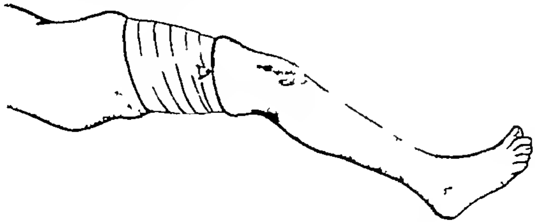

Fig 21

Reactionary œdema The dressing which had been applied loosely is now so tight that it almost acts as a tourniquet

3 **Visible infection**—In a matter of hours the stage of reactionary œdema passes imperceptibly into that of visible infection The part remains swollen the swelling often increases Frequently œdematous muscle herniates through the wound (Fig 22) This produces a stopper effect in an opening which is already inadequate and still further impedes the escape of the products of inflammation Thus in infected wounds there is established a vicious cycle which creates conditions extraordinarily favourable for the onslaught of bacterial invasion It will be appreciated that multiplication of anærobic organisms is particularly facilitated

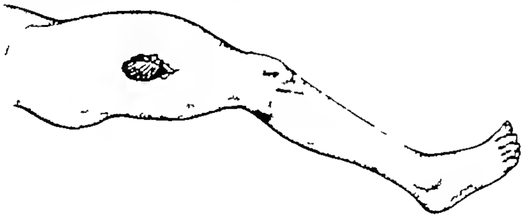

Fig 22

Stage of infection. Œdematous muscle protrudes from the wound and helps to complete the vicious cycle by preventing drainage

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INCISED WOUNDS

Under this heading are classified wounds inflicted by miscellaneous weapons, usually the result of hand-to-hand fighting The bayonet, dagger, knobkerrie and the butt-end of the rifle are usual causative agents Bayonet wounds are often fatal The thrust is usually directed either at the throat or at the loins Soldiers jumping into a trench have become impaled on the upturned bayonet There is rarely external bleeding, and once the bayonet is thrust home the skin and muscle close tightly on the steel so that a considerable effort is required to extract it

Knobkerrie wounds are very often fatal Strictly speaking, these wounds are not true incised wounds, being inflicted by a blunt instrument, but, as also in the case of the butt-end of the rifle, they may be as cleanly cut as if a knife had been used

Bites are not uncommon in close hand-to-hand fighting

ACCIDENTAL WOUNDS

No classification of war wounds would be complete without some reference to this heterogeneous group Accidental wounds may be divided into wounds inflicted in the fighting zone and those inflicted on the lines of communication

In the fighting zone these wounds include tears by barbed wire, and rifle and revolver wounds, self inflicted or otherwise Self-inflicted bullet wounds are usually situated on the dorsum of the foot or in the palm of the hand, and can be recognized by the scorching of the skin around the wound of entry Accidental wounds are usually the result of forgetting to close the cut off after cleaning a rifle

Wounds inflicted on the lines of communication are for the most part due to transport, and are the result of mule kicks, runaway horses and machinery accidents

Though not coming under the heading of accidental wounds, yet occurring most frequently on the lines of communication, are certain wounds due to air raids Not only in these raids have we to consider wounds caused by enemy bombs, but also those caused by pieces of anti aircraft shells, which have on several occasions proved both serious and fatal

CHANGES OCCURRING IN WOUNDED TISSUES

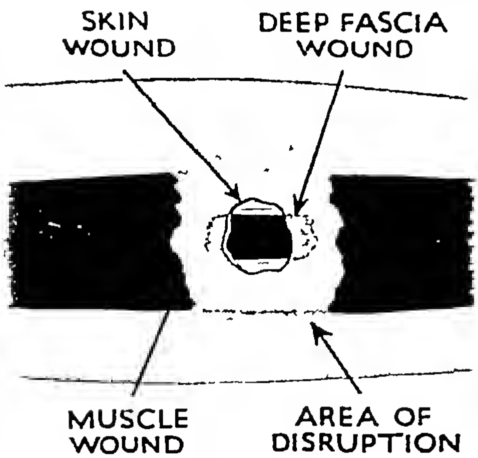


FIG 20

Schematic drawing of a penetrating wound of the soft parts of the thigh immediately after infliction Note the wide separation of the lacerated muscle and the wide area of disruption

1 **Disruption**—The immediate change in the tissues after laceration is disruption, and the amount of disruption depends on the velocity of the missile As has been shown already disruption is seen at its worst in penetrating (syn lodging) wounds Disruption of muscles results in their fasciculi being forced apart and deprived of their blood supply This is the so-called "muscle stupor" of the French surgeons The muscle looks like butchers' meat, it does not bleed when cut and does not contract when stimulated The effects of disruption often extend over a considerable area around the wound (Fig 20), and tissues so affected are a medium *par excellence* for anaerobic infection

2 **Reactionary œdema**—Disruption is soon followed by reactionary œdema

SOURCE OF THE PRIMARY INFECTION—If it is assumed that the missile is sterile the bacteria introduced must come from the clothing skin or from soil which gets into the wound before it comes under medical care Under war conditions clothing is usually covered with mud infected from the skin and possibly contaminated with excreta

In the soil in the air and on clothing most of the bacteria are non pathogenic and are incapable of multiplying in a contaminated wound One reason for this is that the majority of these bacteria are susceptible to the action of lysozyme a bacteriolytic ferment which is universally present in the tissues of the body and which is capable of dissolving such sensitive bacteria

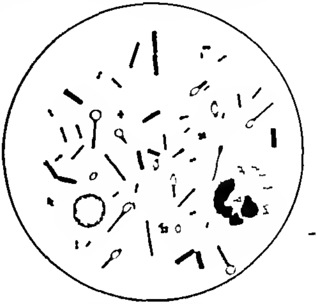


FIG 23

Early stage of wound infection, showing few pus cells, red corpuscles, and many bacteria, especially spore-bearing anaerobes

SPORE BEARING ANAEROBIC BACTERIA (syn clostridia) constitute the most important part of the primary infection of war wounds Normally these bacteria inhabit the intestine of man and animals and their spores are found in soil especially cultivated and manured soil where they remain viable for years in conditions which would be rapidly fatal to the vegetative bacteria These anaerobic bacteria are of low pathogenicity for man in that although we are constantly inhaling the spores in dust and meeting them in gardening or other pursuits they seldom in civil life invade the body If however they are introduced into a wound under conditions which especially favour their growth they multiply and produce acute and fatal diseases such as gas gangrene and tetanus Such favourable conditions exist when in the wound there is devitalized tissue especially muscle and a coincident infection with septic aerobic organisms which grow out and reduce the oxygen tension in the wound

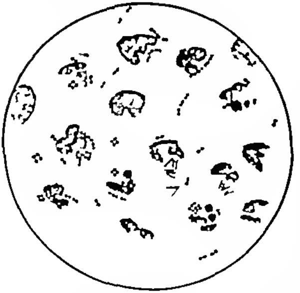


FIG 24

Late stage of wound infection, showing many pus cells and bacteria, especially streptococci and staphylococci

The discharge from a severe septic war wound in the early stages is

CHAPTER III

BACTERIOLOGY OF WOUNDS

NATURE OF THE INFECTION IN WAR WOUNDS

THE infection can roughly be divided into primary and secondary, the former being due to the organisms introduced into the wound at the time of infliction and the latter to infection introduced at some later period

Wright has classified the infecting bacteria of war wounds into serophytes and sero-saprophytes The organisms found in the primary infection are almost all sero-saprophytes, which grow badly in unaltered blood or blood fluids, but which multiply readily when these fluids are "corrupted," as when the alkalinity is reduced by the devitalization of masses of muscle or when the antitryptic power is lessened by the breakdown of leucocytes (pus cells) or other cells, with the consequent release of tryptic ferments In the secondary infection some of the organisms are serophytes, which grow freely in unaltered blood fluids Prominent among these is the hæmolytic streptococcus, some staphylococci and diphtheroid bacilli also fall into this category

Primary infection—The chief micro-organisms causing this are —

I Spore-bearing anaerobic bacilli

(a) Associated with Gas Gangrene—
- B welchii (B aerogenes capsulatus, B perfringens)
- Vibrion septique (B œdematis maligni)
- B œdematiens (B novyi)

Of less importance—
- B fallax
- B histolyticus
- B sordelli

(b) Associated with Tetanus—
- B tetani

(c) Non pathogenic—
- B sporogenes
- B tertius
- And many others

The pathogenic types all produce toxins, and effective antitoxins have been prepared

II Aerobic bacteria

- B proteus
- Coliform bacilli
- Enterococci
- Staphylococci
- Hæmolytic streptococci (uncommon at this stage)

Staphylococci are present at some stage of the infection in practically all severe wounds. These may be derived from the patient's skin or from some outside source. The coagulase test should be performed with the staphylococci isolated. A positive result indicates that the coccus is of a pathogenic type. Staphylococci which give a negative coagulase test are not likely to be of major importance in a wound.

Diphtheroid bacilli are common in the later stages of infection. They are seldom of importance. True diphtheria bacilli have, however, on many occasions been isolated from war wounds, and some patients have suffered from the intoxication which constitutes the disease diphtheria just as they would from a throat infection of the same organism.

B. pyocyaneus, B. proteus and coliform bacilli are found frequently in all stages of infection. Their pathogenicity is low.

METHODS OF COLLECTING SPECIMENS FROM WOUNDS FOR BACTERIOLOGICAL EXAMINATION

In a recent official communication it has been recommended that specimens should be taken on bacteriological swabs, and it has been suggested that the swab-stick be short enough to just lie loose in an ordinary 6 × $\frac{5}{8}$ in. test tube plugged with cotton wool (Fig. 23). This type of swab has obvious advantages, especially for the surgeon in the operating theatre, as when a specimen is required an attendant can remove the cotton wool plug and shake out the swab-stick into the surgeon's hand. The surgeon can then take the specimen and drop the swab back into the test tube without interfering with his asepsis.

Fig. 23. Swab with shortened stick sterilized inside a test tube.

Where possible two such swabs should be taken, especially in cases where anaerobic infection is suspected. This is not essential, but it makes it easier for the bacteriologist to carry out the necessary examinations.

The "swab" method of taking specimens was suggested for the reason that it was very easy, and it was thought that if anything more elaborate were asked for many specimens would not be taken. From the bacteriologist's point of view other methods are often more desirable. He has to make films for direct microscopical examination and also the necessary cultivations, and while a swab is quite good for making cultures it is one of the worst methods of providing material suitable for direct microscopical examination. Other methods of taking specimens involve a little more trouble, but in many instances they help the bacteriologist in his work.

(*a*) Collection of material from a wound with a teat and capillary pipette.—A rubber teat is affixed to the end of a capillary pipette; this is introduced into the wound and a sample of the discharge is drawn up into the pipette from the depths of the wound. This is especially useful where there is a copious discharge or where there is a drainage tube in the wound, as the pipette can be introduced down the tube and discharge withdrawn from the depths.

usually a dark reddish-brown fluid, often foul smelling, containing few pus cells but masses of bacteria (see Fig 23)

Secondary infection—The rate of disappearance of the anaerobic primary infection varies greatly in different wounds according to the severity of the wound, and always persists longer when sloughs or sequestra are present Sooner or later, however, it tends to disappear and to be replaced by the secondary infection, which consists in the main of pyogenic cocci, B pyocyaneus, B proteus, coliform and diphtheroid bacilli, and other organisms found in septic wounds in civil practice (Fig 24)

Source of the secondary infection—Some of these infecting bacteria may reach the wound from the patient's skin or mucous membrane adjacent to the wound, but more commonly they are conveyed to the patient from some other infected individual In pre-Listerian days the spread of B pyocyaneus through a surgical ward was well known, as its presence was revealed by the blue colour of the dressings In the war of 1914-18 this same spread was frequently seen, and it is seen again to some extent in the present war The spread of B pyocyaneus from patient to patient is not usually a matter of great moment to the patient, as this organism is of low virulence but it is of the utmost importance as indicating some flaw in the surgical technique, for where B pyocyaneus can be introduced into a wound in hospital it would be much easier to introduce the hæmolytic streptococcus, which grows more readily in the body fluids

The hæmolytic streptococcus, which is the most important element of the secondary infection, does not advertise its presence by an obvious colour change as does B pyocyaneus, but is only revealed clinically by some serious complication, such as a cellulitis or septicæmia In the last war it was shown that at the casualty clearing station only 15 per cent of the wounds showed the presence of this organism but after a week at a base hospital over 90 per cent of wounds were infected with hæmolytic streptococci

In a very few cases this streptococcus may come from the patient's own skin, but much more commonly it is introduced from an outside source, *e g*, from another patient by faulty technique of dressing, by droplet infection from an attendant with a throat infection, or from infected dust or blankets Hæmolytic streptococci can remain viable and virulent for a considerable time in dust or blankets When infected blankets are shaken or when the floor of a ward is swept, streptococci and other organisms escape into the air and provide a potential source of infection of the wounds It has been shown that if the floor is treated with crude liquid paraffin—spindle oil—or with certain proprietary preparations, subsequent sweeping of the floor does not cause large numbers of streptococci to appear in the air from infected dust, as happens when untreated floors are swept Unless very strict precautions are taken in every hospital ward cross infections with hæmolytic streptococci are bound to occur The subject of hospital infection is fully dealt with in a recent memorandum issued under the auspices of the War Wounds Committee and the London Sector Pathologists

If hæmolytic streptococci are found in a wound they should be tested for the presence of soluble hæmolysin If this is present they may be provisionally accepted as streptococcus pyogenes, if absent, the streptococci belong to one of the less pathogenic groups

Staphylococci nro present nt somo stngo of tho infection in practically all severe wounds These may bo derived from the patient s skin or from some outside source Tho coagulase test should be performed with the staphylococci isolated A positive result indicates that the coccus is of a pathogenic type Staphylococci which give a negative coagulase test are not likely to be of major importance in n wound

Diphtheroid bacilli nre common in tho later stages of infection They are seldom of importnnce True diphtheria bacilli have however on many occasions been isolated from war wounds nnd some patients have suffered from the intoxication which constitutes tho disease diphtheria just as they would from n throat infection of tho same organism

B pyocyaneus B proteus and coliform bacilli are found frequently in all stages of infection Their pathogenicity is low

METHODS OF COLLECTING SPECIMENS FROM WOUNDS FOR BACTERIOLOGICAL EXAMINATION

In a recent official communication it has been recommended that specimens should be taken on bacteriological swabs nnd it has been suggested that the swab-stick be short enough to just lie loose in an ordinary $6\times\frac{5}{8}$ in test tube plugged with cotton wool (Fig 25) This type of swab has obvious advantages especially for the surgeon in the operating theatre as when a specimen is required an attendant can remove the cotton wool plug and shake out tho swab-stick into the surgeon s hand Tho surgeon can then take the specimen nnd drop the swab back into the test tube without interfering with his asepsis

Where possible two such swabs should be taken especially in cases where anaerobic infection is suspected This is not essential but it makes it easier for tho bacteriologist to carry out the necessary examinations

Fig 23 Swab with shortened stick sterilized inside a test tube.

The swab method of taking specimens was suggested for the reason that it was very easy nnd it was thought that if anything more elaborate were asked for many specimens would not be taken From tho bacteriologist s point of view other methods are often more desirable He has to make films for direct microscopical examination and also the necessary cultivations nnd while a swab is quite good for making cultures it is one of the worst methods of providing material suitable for direct microscopical examination Other methods of taking specimens involve a little more trouble but in many instances they help the bacteriologist in his work

(a) COLLECTION OF MATERIAL FROM A WOUND WITH A TEAT AND CAPILLARY PIPETTE—A rubber teat is affixed to the end of a capillary pipette this is introduced into the wound and a sample of the discharge is drawn up into the pipette from the depths of the wound This is especially useful where there is a copious discharge or where there is a drainage tube in the wound as the pipette can be introduced down the tube and discharge withdrawn from the depths

A convenient pipette for the purpose is that illustrated in Fig 26

The inside of the pipette is in process of making, completely sterilized If stored in a tin with the capillary upwards (the easiest way of storage) the inside of the bulb remains sterile indefinitely For use, a rubber teat is fixed to the pipette, the end of the capillary is broken off and the capillary is passed through the flame of a Bunsen burner or a spirit lamp to sterilize

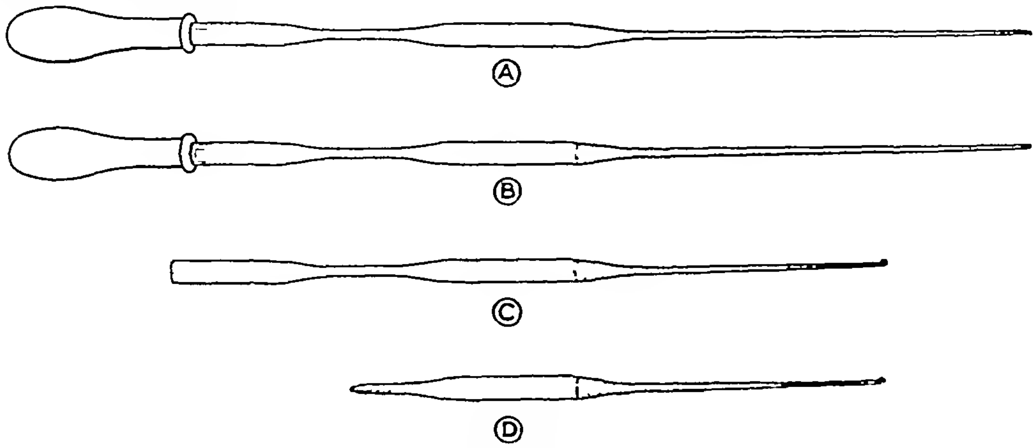


Fig 26

Collection of pus in capillary pipette

A, Pipette and teat
B, Pus collected in pipette
C, Pipette sealed at one end for transmission to near by laboratory
D, Pipette sealed both ends for transmission to distant laboratory

the outside The discharge is then sucked up into the pipette (Fig 26, B), and if the laboratory is handy all that is necessary to do is to seal the distal end of the capillary (Fig 26, C) If the specimen has to be transported some distance the discharge is drawn up into the bulb and the capillary tube is sealed at each end (Fig 26, D)

(*b*) Sloughs, foreign bodies, or other material removed at operation should be placed in test-tubes or other suitable sterile receptacles for transport to the laboratory The wide-mouthed, screw-capped bottles (Fig 27) introduced to bacteriology by McCartney are very suitable for this purpose It is, of course, essential that no preservative be added

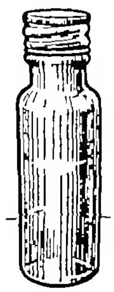


Fig 27

Screw cap bottle for pathological specimens

(*c*) Where discharges are very copious it may be possible to send several cubic centimetres to the laboratory in a sterile test-tube

(*d*) Material extracted from abscesses or closed cavities by syringe or aspirator may be sent to the laboratory in any suitable sterile receptacle

In all cases the material for examination should be sent to the laboratory at once

Information which may be expected from direct examination of material from a wound—Cultures take time to develop, and in many cases useful indications can be obtained by simple microscopical examination of the discharge from a wound as to the nature and intensity of the infection The surgeon must not expect too much, however, as there are few bacteria which can thus be positively identified. Such an examination will give information as to whether the infection consists mainly of spore-bearing anaerobic bacilli or whether it is of the coccal type. Sometimes large numbers of long chained streptococci may be found; here then is a reasonable assumption that such are hæmolytic streptococci and, in cases of urgency, appropriate treatment may be commenced without waiting for cultural confirmation.

Large numbers of B. welchii or other anaerobic bacilli have frequently been found in severe wounds in patients who never developed gas gangrene. If therefore organisms resembling B. welchii are seen in the discharge, even in large numbers, it is of the utmost importance that the surgeon should not assume that the case is one of gas gangrene or even that it is one which is likely to develop gas gangrene, although of course the possibility exists.

BACTERIOLOGICAL CONTROL OF PRIMARY AND SECONDARY SUTURE

Primary suture (see Chapter X).—If the wound is surgically cleansed and sutured before the contaminating bacteria have had time to grow out, no bacteriological control of the operation is possible. Swabs from the depths of the wound should however be taken to ascertain the extent and nature of the primary contamination. If the cleansing operation is delayed for more than six or eight hours the only examination which will help the surgeon is a direct microscopical examination of fluid from the depths of the wound, as much more would be lost by waiting twenty-four hours for cultural results than would be gained by knowing the exact nature of the infection. If at the time of the proposed operation it was found that bacteria had grown out in considerable numbers the surgeon would be taking a great risk in completely closing the wound.

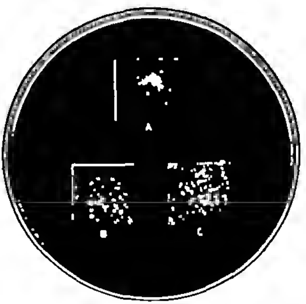


FIG. 28.

Antibacterial action of pus from a war wound.

Drops of pus placed on an agar plate and incubated under a cover slip.

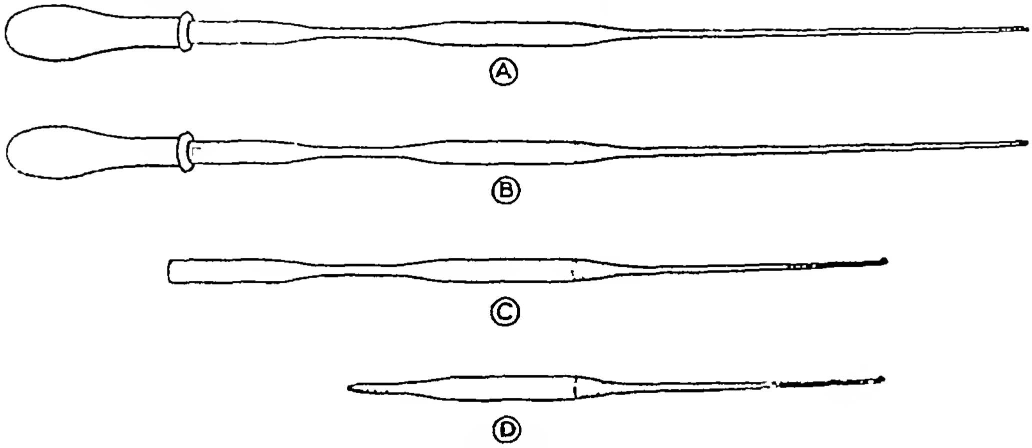
A. Unaltered pus. No growth except a few colonies in the film of fluid pressed out from the pus by the weight of the cover-glass.

B. Same pus heated to 47° C. to kill the pus cells. Many colonies throughout the pus.

C. Same pus, sufficient carbolic acid to make a concentration of 1 : 300. The pus cells are killed and many colonies appear throughout the pus.

Secondary suture (see Chapter XVIII).—In the 1914-18 war a standard was laid down by Carrel that if not more than one microbe to every five or six microscope fields could be seen in a film of pus, and if streptococci were absent, the wound could be sewn up. It was found that the results of secondary suture depended much on

A convenient pipette for the purpose is that illustrated in Fig 26 The inside of the pipette is in process of making, completely sterilized If stored in a tin with the capillary upwards (the easiest way of storage) the inside of the bulb remains sterile indefinitely For use, a rubber teat is fixed to the pipette the end of the capillary is broken off and the capillary is passed through the flame of a Bunsen burner or a spirit lamp to sterilize



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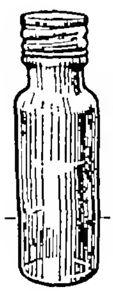

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Screw-cap bottle for pathological specimens

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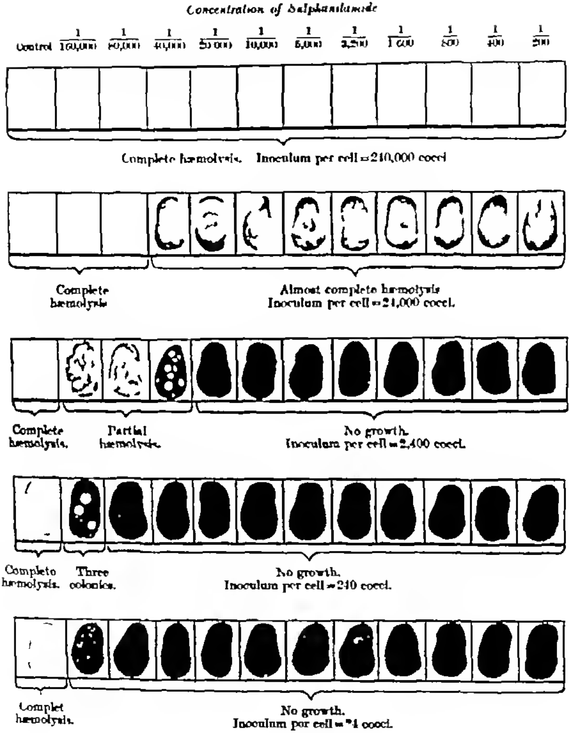

FIG 29

Antibacterial power of sulphanilamide on different numbers of hæmolytic streptococci.

the time at which the operation was performed If optimum conditions were obtained wounds could be successfully sutured which showed a far larger number of bacteria than Carrel had laid down as permissible, and that the presence of streptococci was not a bar to the secondary suture The leucocytes in fresh pus (that which had exuded within eight hours of dressing a wound) have an enormous power of destroying the bacteria which infect war wounds (Fig 28), but this destruction can only be counted on when conditions are such that the walls of the wound are closely opposed and the bacteria have no opportunity of growing out in pools of fluid or dead spaces away from the leucocytes

Carrel's standard was a rough one and one which at the present day, with effective antistreptococcal chemotherapy at our disposal, need not be adhered to One of the chief dangers in regard to secondary suture was the possible spread of infection, especially of streptococcal infection, but this can now be controlled by the administration of one of the sulphonamide drugs, especially sulphapyridine or sulphathiazole Two grams of either of these drugs administered two hours before the operation will ensure that there is an adequate concentration in the blood at the time of the operation, and if the administration of the drug is continued for two days it is unlikely that there would be any spread of the streptococci If the wound contained pathogenic staphylococci at the time of suture sulphathiazole would be the most suitable drug, as it has a considerably greater antistaphylococcal power than sulphanilamide or sulphapyridine

CONDITIONS WHICH INHIBIT THE ACTION OF THE SULPHONAMIDE COMPOUNDS

Observations have shown that the application of the sulphonamide drugs to recently inflicted wounds delays or completely inhibits infection with hæmolytic streptococci and the anaerobic bacteria associated with gas gangrene While this is true of the recently inflicted wound, there are conditions which develop in wounds in which the infection has become established which may completely inhibit the bacteriostatic action of these drugs

It has been shown that in the following conditions the bacteriostatic action of the sulphonamide drugs disappears —

1 Presence of large numbers of bacteria
2 Presence of extracts of bacteria
3 Presence of certain chemicals, *e g* , para-amino-benzoic acid
4 Presence of "peptones"
5 Presence of pus fluid

The experiment illustrated in Fig 29 illustrates the effectiveness of sulphanilamide as a bacteriostatic agent in human blood in the presence of a small number of hæmolytic streptococci and its ineffectiveness when a large number of such cocci are present

The following experiment shows the powerful anti sulphonamide effect of pus fluid Pus from an empyema was boiled to kill the relatively small number of pneumococci present, and was then centrifuged to remove the pus cells Dilutions of the supernatant fluid were mixed in equal

CHAPTER IV

COMPRESSION PHENOMENA

(1 Blast 2. Crush Syndrome 3 Caisson Disease)

As a result of the ultra mechanization of warfare the principal damaging factor is a massive crushing force rather than penetration by bullets or shell fragments.
—Lambe G. Smith

BLAST

BLAST though not a new phenomenon has acquired much greater prominence than formerly. In the 1914-18 war the terrific compression or rarefaction wave set up by the detonation of high explosives usually spent itself in open country. In the bombing of towns such waves (Fig. 30) are created in streets and other confined spaces and cause effects

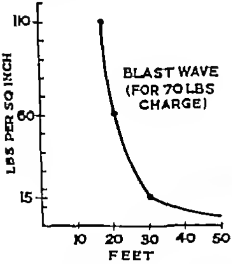

Fig. 30

The curve of blast pressure. Note how rapidly the pressure drops. Thirty feet away it is only 15 lbs. per square inch. (A.R.P. Handbook No. 5.)

Fig. 31

Severe haemorrhage in right lung of a rabbit which had been exposed to blast from the explosion of oxygen and hydrogen in a balloon. The animal was placed so close to the explosion that the right side shielded the other (S. Zuckerman).

varying from general mutilation to partial or even entire loss of clothing. Most of the cases of blast have come from bombed houses. If the victim is not killed outright the organs most frequently affected are the lungs. Osborn calls the condition pulmonary concussion.

Zuckerman carried out a series of experiments in which he exposed various animals to blast. The experiments were so arranged that the animals did not sustain external injury and there was no question of penetrating wounds. The outstanding pathological lesion was bilateral traumatic haemorrhage in the lungs (Fig. 31), and when blast had been sufficient to kill the animal, blood was found in the bronchial tree. Zuckerman concluded that blast bruises the lungs by its impact upon the body wall as opposed to upon the hial tree proportions with blood infected with staphylococci, and containing sulphapyridine in a concentration of 1 40,000 The number of colonies which developed was as follows —

	Number of Colonies
Infected blood + normal saline (control)	44
Infected blood + sulphapyridine	0
Infected blood + sulphapyridine + pus fluid diluted sixty-four times	40

The pus fluid, therefore, even when diluted many times, inhibited the bacteriostatic action of sulphapyridine

These experiments, and many others, show that however valuable is the administration of the sulphonamide drugs in recently inflicted wounds it must not be expected that their local administration will be rapidly effective in wounds containing much pus and large numbers of bacteria It has been found, however, that in granulating wounds the application of considerable quantities of the sulphonamide drugs rapidly clears the wounds of sulphonamide-sensitive organisms such as hæmolytic streptococci

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CHAPTER IV

COMPRESSION PHENOMENA

(1. Blast 2. Crush Syndrome 3. Caisson Disease)

> As a result of the ultra mechanization of warfare the principal damaging factor is a massive crushing force rather than penetration by bullet or shell fragment
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BLAST though not a new phenomenon has acquired much greater prominence than formerly In the 1914 18 war the terrific compression or rarefaction wave set up by the detonation of high explosives usually spent itself in open country In the bombing of towns such waves (Fig 30) are created in streets and other confined spaces and cause effects

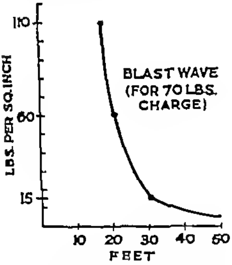

Fig 30

The curve of blast pressure Note how rapidly the pressure drops Thirty feet away it is only 15 lbs. per square inch (A R P Handbook No 3)

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Severe haemorrhage in right lung of a rabbit which had been exposed to blast from the explosion of oxygen and hydrogen in a balloon. The animal was placed so close to the explosion that the right side shielded the other (S Zuckerman)

varying from general mutilation to partial or even entire loss of clothing Most of the cases of blast have come from bombed houses If the victim is not killed outright the organs most frequently affected are the lungs Osborn calls the condition pulmonary concussion

Zuckerman carried out a series of experiments in which he exposed various animals to blast The experiments were so arranged that the animals did not sustain external injury and there was no question of penetrating wounds. The outstanding pathological lesion was bilateral traumatic haemorrhage in the lungs (Fig 31) and when blast had been sufficient to kill the animal, blood was found in the bronchial tree Zuckerman concluded that blast bruises the lungs by its impact upon the body wall as opposed to its effect upon the air in the bronchial tree

Necropsy findings—Everywhere on the pleural surfaces there are many small, fresh hæmorrhages The trachea and bronchi show numerous petechial hæmorrhages, and there is some blood on the surface of the mucous membrane The cut surface of the lung is most striking, there are bright red points of hæmorrhage to be seen everywhere Professor Shaw Dunn states that these hæmorrhagic spots, which vary in size from a pin's head to a finger nail, are due to inhaled blood and are therefore secondary phenomena The primary lesions are shown in Fig 32 The damage to the lungs is more severe in younger subjects because of their comparatively elastic thoracic walls

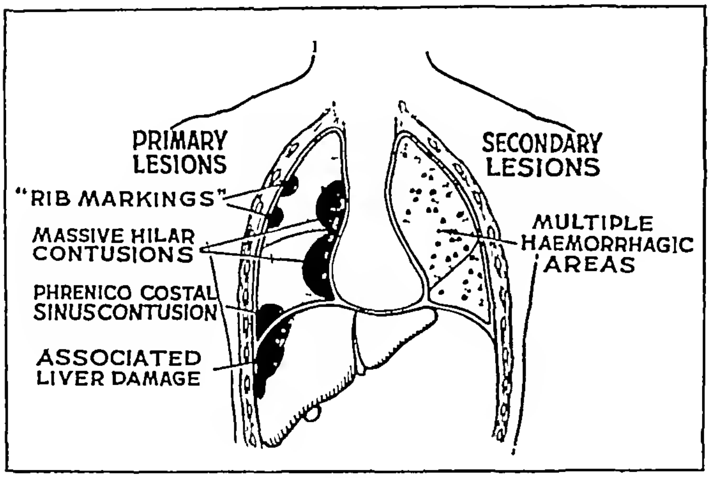

Fig 32

The principal lesions found at necropsy in blast injuries of the lungs (*After Shaw Dunn*)

Histology—The characteristic findings are (*a*) an extensive outpouring of erythrocytes, sometimes accompanied by fibrin formation and a deposit of blood pigment, (*b*) rupture of elastic tissue and capillaries, (*c*) evidences of secondary infection with streptococci (broncho pneumonia)

Clinical features—It is often difficult to assess the relative importance of blast on the lungs when there are other injuries

Shock—There is a rapid development of severe shock

Dyspnœa is a constant feature, particularly extreme respiratory dyspnœa

Cyanosis is often striking, and in cases where recovery has followed, it tends to disappear after twenty-four hours Thereafter the picture may be confused by the administration of sulphapyridine

Pain in the chest is not unusual

Hæmoptysis is common within an hour or two of the injury, and it tends to be repeated

Physical signs—That blast injury to the lungs is present should be suspected when there are diminished movements of the diaphragm, fullness of the chest giving it an emphysematous appearance, and impairment of resonance at one or both bases It is usual to find the lower chest ballooned, especially in the region of the lower costal margin (Fig 33)

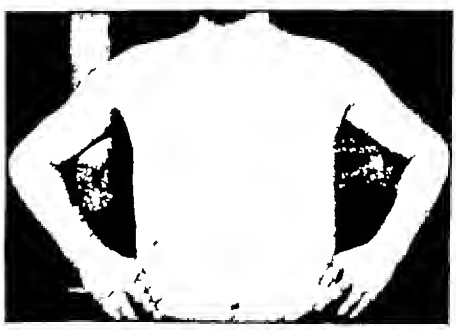

Fig 33

Patient after blast injury Note fullness of lower part of the chest (R S Allison)

Signs of lobar pneumonia, accompanied by pyrexia, often develop within twelve to twenty-four hours

The effects of blast are much more disastrous in patients with lungs already diseased

Radiological findings—The most typical sign is heavy mottling scattered over large areas of the lung fields (Figs 34 and 35)

Radiograph showing typical blast injury of the lungs.

Fig 34

About thirty hours after injury Heavy mottling of left lung field less on right (O Reilly and Gloyne)

Fig 35

Radiograph taken within twelve hours of injury Heavy mottling of the whole left lung field and right mid zone

THE EFFECTS OF BLAST ON THE ABDOMEN

Too little attention has been paid to the effects of blast upon the abdomen as opposed to the thorax It is probable that in most cases damage to the intestines similar to that of the lungs but on a minor scale occurs melæna has been noticed in a number of these cases

Pain in the abdomen is often an important feature and difficulties surrounding the diagnosis are considerable It is true that laparotomy has been performed with negative findings on several occasions Nevertheless a subparietal rupture especially of the colon has been revealed by timely operation sufficiently often to prompt the surgeon when in doubt to look and see —under local anæsthesia

THE EFFECT OF BLAST UPON THE CENTRAL NERVOUS SYSTEM AND ORGANS OF SPECIAL SENSE

It is not to be wondered at that the central nervous system suffers severely and lesions ranging from mental aberration to weakness of the limbs or temporary paresis are commonplace After being subjected to blast even animals show signs of their ordeal Cows ceased to eat and had to be slaughtered a dray horse suffered from mild paralysis Rabbits hopped aimlessly and could be picked up by hand (Burston)

Ruptured ear-drums are almost the rule Some of the patients develop purulent otorrhœa

MANAGEMENT AND TREATMENT

If adequate cover is not available, the effects of blast can be minimized by lying down flat upon the ground In cases of asphyxia due to blast, Schafer's method of artificial respiration is contraindicated The treatment of blast belongs to the resuscitation department and, unless the surgeon is absolutely compelled, the patient should not be taken to the operating theatre until the condition has been remedied There is no need for trepidation in administering an adequate dose of morphia to patients suffering from blast injury to the lungs It is obvious that if a patient is seriously shocked priority will be given to the treatment of the shock One of the chief principles of the treatment of blast injury is to immobilize the patient and disturb him as little as possible for a period of several days

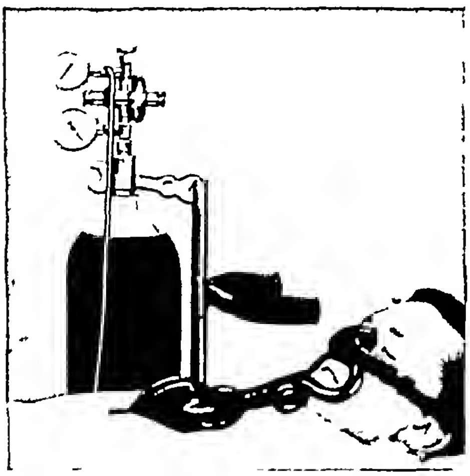

Fig 36
Administration of oxygen with a B L B mask

Oxygen administered preferably by a B L B mask (Fig 36), should be the rule Oxygen therapy produces striking and lasting results in comparatively mild cases

In cyanotic patients with much dyspnœa venesection has been recommended Sulphapyridine has been given prophylactically, in doses of two tablets four-hourly but this appeared to have little effect in preventing the development of pneumonia

It is essential that the anæsthetist should bear in mind the possibility of blast before he anæsthetizes the patient for an operation elsewhere in the body. If a patient suffering from blast must be operated upon, local or intravenous anæsthesia should be employed

In patients suffering from the effects of blast upon the central nervous system the first consideration in treatment is absolute rest In addition magnesium sulphate per rectum has proved of value, and in a few cases 40 c c of a 15 per cent solution of hypertonic saline given intravenously has been praised by some observers

CRUSH SYNDROME

Few British surgeons had heard of the crush syndrome until 1941 for it had not been described in the English literature According to Bywaters by the end of the 1914-18 war the syndrome was well recognized by the Germans Even before this era the condition was not unknown, nineteen cases had been recorded in connection with the Messina earthquake in 1909

In order to be clear as to what is meant by this term, a description of a case will be given:

As a result of bombing masonry collapsed, and the patient's thigh was pinned beneath debris for about two hours. He was extricated and taken to hospital, where he was treated for shock with good effect. Radiography revealed no bony injury, but obvious extensive muscle damage and hæmatoma formation had occurred in the affected limb. About twenty-four hours later his urinary output became severely diminished. In spite of a high fluid intake anuria followed.

Too often death from uræmia results, usually about the seventh or eighth day. The problem before us is to institute effective treatment. In order to do so the cause of the syndrome must be understood. At the present time it can hardly be said that the underlying pathology has passed the stage of ingenious hypothesis.

Etiology.—So akin is this phenomenon to anuria following incompatible blood transfusion that the theory of the uriniferous tubules becoming choked with disintegrated erythrocytes was appealing. Since many of the sufferers of the crush syndrome had received blood or plasma transfusion, it was not unnatural that inquiring minds demanded that anuria from precipitation of red cells as a result of the transfusion should be eliminated before a new explanation was sought. Fortunately, in the recent literature a few cases have been reported where no transfusion has been given, and if it is correct that the syndrome is not a new clinical entity, cases also occurred before transfusion was in general use. Other theorists suggest that the kidney damage is caused by katabolites of a toxic nature, *e.g.* histamine released from the mass of crushed muscle. Still other theories have been put forward, but they seem to be poorly supported by biochemical or pathological findings, although we should take into consideration that the sulphonamides, particularly sulphapyridine, predispose to hæmaturia and oliguria.

Prevention.—When it is realised that renal failure is a possible sequel of a crush, it may be possible to institute effective measures before the kidney function fails. Sir Leonard Hill advocates copious oxygen therapy. Curphey suggests that an Esmarch's bandage be applied to the limb directly after the victim's extrication in order to prevent the mass release of toxins. If the limb is spared amputation the bandage should be loosened inch by inch. Cohen finds that arterial stupor is quite common when blood is extravasated in the neighbourhood of an artery, and if at the end of six hours or so the distal pulse has not returned he advises that at any rate the main vessels should be exposed and cleared of surrounding blood clot. If time permits periarterial sympathectomy can be performed with advantage. The incision should be left unsutured; this adds nothing to the risk of infection of the damaged area.

Professor Harris wonders whether the crush syndrome is not, in fact, a continuous interference syndrome. The zeal with which some of the reported cases have been investigated by every conceivable means deprives the patient of the rest he surely needs.

Treatment of the anuria.—While there is a certain amount to be said for Professor Harris's view, a considerable experience of anuria in civil surgery has convinced me that to sit with folded hands and hope that the patient will pass urine is rarely rewarded by anything but remorse that more active treatment was not started earlier. In the anuria of the crush syndrome the problem of rational treatment is easier than in cases occurring in civil practice where an obstructive lesion e g calculous anuria, must be eliminated before attempting to stimulate renal function There seems to be no reason for not proceeding in precisely the same manner as in non-obstructive anuria from other causes —

1 Ascertain whether low blood pressure i e, shock is the cause The most reliable indication is the blood pressure If the blood pressure is low do nothing until this has been remedied by plasma transfusion and other means It should be noted that in several of the reported cases of crush syndrome it is clearly stated that the patient had recovered from shock

2 If the blood pressure is adequate, administer isotonic sodium sulphate intravenously very cautiously, and not exceeding 1 to 1½ pints unless the urinary flow is re-established While this is proceeding, hot packs are applied to the loins

3 Take the patient to the operating theatre and administer a small (half) dose of spinal anæsthetic A spinal anæsthetic, of itself, has been known to terminate reflex anuria but an additional reason for giving the spinal anæsthetic is that it will help to make cystoscopy painless Through the cystoscope ureteric catheters are passed, and we wait for a full quarter of an hour to see if urine drips out of the catheters On many occasions this enterprise is rewarded, and sodium sulphate or alternatively, 5 per cent glucose is given intravenously in proportion to the urinary output

4 Carry out renal decapsulation There appears to be too much hesitation in performing this operation With the area already partially anæsthetized by the spinal anæsthetic, local infiltration is perfectly satisfactory One kidney should be exposed and decapsulated without delivery of the organ, and if all goes well the other side can be treated similarly

CAISSON DISEASE, WITH SPECIAL REFERENCE TO SUBMARINE SALVAGE

This is a convenient place to consider Caisson disease, for blast has been likened to an exaggerated form of this condition

The symptoms and signs of compressed air illness are due to the liberation of bubbles of nitrogen from the blood into the tissues following rapid decompression (Fig 37) It is convenient to classify casualties into —

1 "*Bends*"—This is manifested by pains in the joints The pain is severe and the limb is flexed, hence the colloquial term The bubbles of nitrogen are situated in cartilage or areolar tissue The knee and the elbow are commonly affected
2 "*Sand-boy's itch*"—There is mottling and patchy discoloration of the skin
3 "*Chokes*"—The main symptom is a sense of constriction in the chest and dyspnœa
4 *Neurological type*—Nystagmus, diplopia, deafness, convulsions and coma are among the many phenomena
5 *Fulminating type* is often fatal At necropsy numerous bubbles are found in the heart and lungs

The Davis apparatus designed for escaping from submarines (Fig 38) is an oxygen breathing appliance which will last half an hour In theory it is excellent but at the inquiry into the loss of H M Submarine Thetis Haldane advanced the opinion that administration of pure oxygen in the Davis apparatus to men already suffering from a high degree of CO poisoning caused uncontrollable vomiting This would lead to removal of the face piece under water and to loss of life By experiment Haldane found that the ill effects were minimized by administration of air instead of oxygen

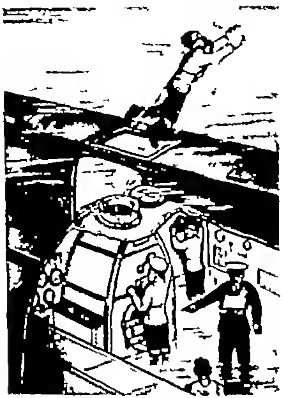

Fig 37
Escaping from a submarine (After S Jeffiams)

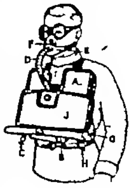

Fig 38
The Davis submerged escape apparatus.
A Horn of breathing bag B Oxygen flask C, Regulating valve D Flexible tube E, Mouthpiece F Nose clip G Valve for manifold, H Exhaust valve J Breathing bag (After S Jeffiason.)

Survivors with compressed air illness should be put into a decompression chamber as soon as possible If there is no indication of pre-existing oxygen poisoning oxygen therapy is indicated The patients are *re*compressed until all the symptoms are relieved and *de*compressed according to the scale from the Diving Manual

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CHAPTER V

SHOCK AND ITS TREATMENT

THE term shock was first used by James Latta of Edinburgh in 1795 to describe the clinical condition which results from injury and which he thought was due to a state of collapse of the circulation Shock however can develop quite apart from physical trauma—for example shell shock anaphylactic shock and psychical shock are well known Thus it is necessary to qualify the term

TRAUMATIC SHOCK

Etiological factors—The circulation depends on the action and force of the heart beat the peripheral resistance and the volume and viscosity of the blood Interference with any of these factors will if severe produce a fall of blood pressure and a state of collapse of the circulation

THE FORCE OF THE HEART BEAT depends mainly upon the venous inflow It is diminished by lowered arterial resistance and degeneration or inflammation of the heart musculature which in turn may be due to infection or toxæmia By lowering of the systolic blood pressure to 80 mm Hg the force of the heart beat is diminished If the systolic pressure is lowered further to about 60 mm Hg collapse of the circulation occurs unless steps are taken to prevent it

PERIPHERAL RESISTANCE is lowered by dilatation of the capillaries This causes stasis and consequent loss of plasma by exudation into the tissues

DIMINISHED BLOOD VOLUME—Hæmorrhage vomiting profuse sweating and what is very important in cases of shock exudation of plasma from the capillaries all cause reduction in the volume of the circulating blood

INCREASED VISCOSITY OF THE BLOOD—Obviously if fluid other than whole blood is removed from the circulation the blood which remains will become more viscid It should be noted particularly that following this reasoning there is likely to be a relative increase in the cellular element of the blood which remains

There is no doubt that hæmoconcentration occurs in burns but as yet hæmatological studies in cases of shock have not produced uniform findings

Whatever may be the cause of shock it must be insisted upon that the condition is a *failure of the circulation* Clinically this is shown by a fall of blood pressure The fall in blood pressure follows rather than initiates the onset of shock It will occur only when the compensatory mechanism of the body which maintains the circulation commences to break down

Although there are exceptions (see p 39) the best criterion of the degree of shock is the blood pressure A sphygmomanometer cuff should be left in position, and subsequent readings taken frequently

The injury which produces shock often causes hæmorrhage at the same time Under these circumstances the fall of blood volume is more rapid and consequently the state of shock is more pronounced

In 1917 the Medical Research Council inaugurated a Committee to investigate traumatic shock The present clinical conception of shock is largely due to the findings of that Committee

Traumatic shock may be divided into two varieties—primary and secondary

Primary shock comes on immediately after the injury The rapidity of the onset suggests that it is due to a reflex inhibition of the heart accompanied by a splanchnic vasodilatation Experimentally it is said to be prevented by blocking the nerves supplying the part before the injury is incurred Primary shock is seen typically following a severe blow on the epigastrium or the testis Death may occur as the result of such an injury with no external marks of violence The extent of the primary shock depends on the extent of the area involved by the injury It is for this reason that an extensive superficial burn is more serious than a small deep one The psychical make-up of the injured individual is a factor in the development of the condition, for instance, it is well known that a patient fearful before an operation is more prone to suffer shock than one who is relatively unperturbed

Secondary shock develops at a varying interval after the injury It is influenced by factors which to a great extent can be controlled These are cold, pain, hæmorrhage and toxæmia Again the psychological elements of fear and mental stress must be taken into consideration

THE SYMPATHETIC NERVOUS SYSTEM IN RELATION TO SHOCK

The factors producing shock, whether primary or secondary cause undue stimulation of the sympathetic nervous system The function of the sympathetic nervous system is to maintain the blood pressure and increase the rate of the heart beat Stimulation of this system causes constriction of the arterioles of the skin and splanchnic area, but *dilates* the vessels in the skeletal muscles, thus making available the maximum amount of material for muscle activity

Injection of adrenalin, or an increase of CO_2 in the blood has, to a great extent, the same effect as stimulation of the sympathetic Impulses are continually entering the sympathetic system from all parts of the body by the afferent nerves, and impulses are transmitted by the white rami communicantes to the organs which it innervates Over-stimulation of the system inaugurates the onset of shock

CLINICAL FEATURES OF TRAUMATIC SHOCK

In well-established cases there is an anxious expression, thirst, vomiting and sweating Respirations are shallow These symptoms are accompanied by a considerable fall in the blood pressure, the pulse rate rises to 120 to 160 per minute. The temperature is subnormal. In progressive cases the patient passes into a state of apathy and torpor which precedes death.

What are the changes in the circulation which give rise to these phenomena? McMichael's table is helpful in visualizing the events taking place in the blood vascular system.

MECHANISM OF SHOCK

Disproportion between content and capacity of vascular system (i.e., reduction in blood volume or increased capacity of smaller vessels)

↓

Diminished pressure in great veins near heart

↓

Decreased diastolic filling of heart

↓

Decreased cardiac output (Starling's Law)

↓

Fall in blood pressure

↓

Decreased pressure in carotid sinus

Acceleration of pulse	Compensatory sympathetic stimulation (Vasoconstriction, sweating, skin and visceral pallor)

It may be that in the future the measurement of blood volume or the specific gravity of the peripheral blood will prove to be a reliable indicator of the degree of shock. At the present time blood pressure readings, especially repeated readings, are the best scientific measures at our disposal. Good as are blood pressure readings, implicit trust cannot be placed in them. Cases are encountered where the blood pressure is comparatively normal and yet the patient is in a state of shock. In the presence of extensive injuries, when the blood pressure is found to be comparatively normal, the case must be viewed with the greatest suspicion. Such patients usually develop acute circulatory collapse later, perhaps in the middle of operation. A normal blood pressure in these circumstances is due to the patient originally having a raised blood pressure or to vasoconstriction occurring *pari passu* with the decrease in blood volume because of hypersecretion of adrenalin. The latter phenomenon is not uncommon and is seen especially in cases of burns. It is not difficult to recognize because with the exception of lowered blood pressure most of the signs of shock are present (Edwards).

Estimation of blood volume by plasma transfusion.—While blood pressure still remains the best index of a shocked patient's fitness for operation, a very useful aid in assessing the degree of shock has been devised by Bushby, Kekwick and Whitby, namely, a simple method of estimating blood volume. When the known volume of plasma is added to the unknown volume of blood, the total number of red cells is unaffected. The red cells as expressed by the hematocrit packed cell reading or hemoglobin percentage can therefore act as an indicator of the amount of the dilution brought about by the transfusion.

The formula for estimating blood volume is:—

$$V = \frac{Py}{X - y} = \frac{\text{The volume transfused} \times \text{the new hemoglobin reading}}{\text{The difference between the hemoglobin readings before and after transfusion}}$$

If, for example, the hemoglobin readings before and after the transfusion of 1,000 c.c. of plasma are 44 and 34 per cent respectively, the blood volume $= \frac{1000 \times 34}{10} = 3400$ c.c. The estimation is, of course, fallacious if bleeding is taking place, and it is important that the plasma should be transfused quickly

Marriott and Kekwick have pointed out that blood or plasma transfusion in cases of severe shock should be rapid—at the rate of 1 pint per fifteen minutes or even faster The amount transfused depends on the severity of shock Patients showing significant reduction of blood volume will require 1½ to 4 pints of blood or plasma

AN ANALYSIS OF THE CLINICAL AND PATHOLOGICAL DATA

Empirical treatment is unsatisfactory and unscientific Much as we may wish that it were otherwise, it is only too evident that in formulating rational treatment for traumatic shock we are handicapped, perhaps more than in any other condition, by the almost complete lack of specific necropsy findings Unremitting labour in the laboratory has so far produced comparatively little to help us It is for these reasons that it is doubly necessary to analyse every morsel of relevant clinical and pathological data

The over-stimulation of the sympathetic nervous system causes —

(*a*) The excessive sweating

(*b*) Cutaneous vasoconstriction—hence the pallor of the skin

(*c*) Vasodilatation of deep-seated capillaries, especially those in the muscles It should be noted particularly that vasodilatation does not take place mainly in the splanchnic area Proof of this is afforded at laparotomy and post-mortem There is pallor of this area rather than congestion

A slowing of the peripheral circulation leads to anoxæmia of the tissues As a result of the accumulation of blood in the capillaries and the increased permeability of their walls, blood plasma exudes into the tissues This in a large measure accounts for the loss in blood volume The rapid, shallow respirations are due to the failure of the respiratory centre, the result of the fall of blood pressure

CONTROVERSIAL PROBLEMS

Cutaneous vasoconstriction can be looked upon as Nature's attempt to compensate for the fall in blood pressure Freeman is of the opinion that stimulation of the sympathetic inaugurates the cycle by producing vasoconstriction, with capillary dilatation in the musculature which induces a peripheral asphyxia In criticizing this statement McDowall points out that shocked patients do not become cyanosed

Deep-seated vasodilatation is probably due to the fall of blood pressure and is not a primary cause in the production of shock Probably it occurs as the result of exhaustion of vital medullary centres

Central exhaustion and CO_2 loss—These both play a part When the CO_2 tension falls below a certain level there is depression of the vasomotor centres The CO_2 tension in the blood can be diminished by the hyperpnœa caused by pain, mental stress and anæsthesia, and the result is failure of the vital centres and the circulation, together with a fall in blood pressure

The CO_2 loss, however, is not the main cause of shock There is abundant experimental evidence that exhaustion of the central nervous system plays an important part This, with stimulation of the sympathetic system starts the vicious cycle The part played by both the cortical and medullary portion of the adrenals is also important but more experimental work is needed to define their influence

Toxæmia—The clinical condition of severe toxæmia e g that due to severe peritonitis is indistinguishable from that of shock The term collapse has been used to describe this condition but it is the same as shock

The part played by toxæmia in the production of shock is still uncertain Multiple or extensive wounds are followed by severe shock and especially if the abdominal viscera are injured Although there is little experimental evidence to support the view yet there is little doubt that toxæmia does play a (sure) part in producing the clinical picture of shock

The recent work of Slome and the late O Shaughnessy however denies the influence of any toxic agency but shows that the nervous factor is all important There is however no doubt that the onset of shock may coincide with the removal of a tourniquet which apparently allows some toxin to enter the circulation though perfusion experiments with blood from an injured limb do not demonstrate the presence of any deleterious substance in the blood from such a limb It was thought that histamine was the substance responsible for the onset of shock but there is no real evidence of this and moreover the post mortem appearance in death from histamine shock shows intense congestion of the intestines whereas in traumatic shock they are bloodless The clinical evidence however is sufficiently strong to indicate that a tourniquet should be placed as near the injured part as possible and furthermore some surgeons prefer to amputate if this is necessary without removing it and to include the tourniquet in the part removed

Excitement and psychical stress—It is difficult to assess the importance of these factors though they are very real The idea was developed by Crile and his associates who suggested methods whereby they were avoided (Anoci association)

PREVENTION

The prevention of shock is a subject which has received much attention in civil surgery and rightly so It is not proposed to discuss this aspect of shock in detail here This does not imply that measures to prevent shock are irrelevant on the contrary we must do everything possible to prevent an already shocked patient becoming still further shocked by avoiding untimely ill-chosen procedures In this connection the following cardinal points must be emphasized

Even in the direst emergency after hæmorrhage has been controlled adequate resuscitation must precede operation When to operate calls for a high degree of surgical judgment

The resuscitation ward—During the 1914 18 war it was proved by Cowell and Fraser that pain cold toxæmia and hæmorrhage were important factors in determining the onset of secondary shock Secondary shock was largely eliminated when resuscitation wards were introduced

A resuscitation ward can only be organized in a properly equipped hospital of the casualty clearing station or base type and it should be under the control of a resuscitation officer who has the required experience and course, fallacious if bleeding is taking place, and it is important that the plasma should be transfused quickly.

Marriott and Kekwick have pointed out that blood or plasma transfusion in cases of severe shock should be rapid—at the rate of 1 pint per fifteen minutes or even faster. The amount transfused depends on the severity of shock. Patients showing significant reduction of blood volume will require 1½ to 4 pints of blood or plasma.

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A slowing of the peripheral circulation leads to anoxæmia of the tissues. As a result of the accumulation of blood in the capillaries and the increased permeability of their walls, blood plasma exudes into the tissues. This, in a large measure, accounts for the loss in blood volume. The rapid shallow respirations are due to the failure of the respiratory centre, the result of the fall of blood pressure.

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The CO_2 loss, however, is not the main cause of shock. There is abundant experimental evidence that exhaustion of the central nervous system plays an important part. This, with stimulation of the sympathetic system, starts the vicious cycle. The part played by both the cortical and medullary anæsthesia Novikov performed 154 major amputations under local anæsthesia with a mortality of 14 7 per cent These surgeons advocate the use of large quantities of very dilute solution of novocain e g ½ per cent This is injected around but not into the wound and each tissue infiltrated thoroughly Other surgeons have used intravenous anæsthesia and are enthusiastic about the results This has proved an excellent method when dealing with traumatic cases in civil practice when the services of a skilled administrator of gas and oxygen are not available

* * * * * * * *

In the long run those guiding principles which dominate all branches of surgery in peace hold good even more forcibly in the surgery of war Speed in operating is a great acquisition but it takes second place to gentleness the tissues should be caressed as Moynihan expressed it

THE SHOCK-HÆMORRHAGE SYNDROME

In the frequently encountered shock hæmorrhage syndrome it is difficult to assess which moiety predominates This should not be an occasion to ponder If it is certain that the patient has lost a considerable amount of blood no time should be lost in performing blood transfusion preferably by the drip method

THE TREATMENT OF TRAUMATIC SHOCK

First aid—First aid workers should be taught the value of elevation With the body supine and the blood pressure low vertical elevation of a limb renders it almost bloodless not by gravity alone but as Lister showed by reflex contraction of the arteries A single-handed first-aid worker can raise both legs by the ankles and then stepping astride the patient s head by pulling on the legs can raise the pelvis (Fig 30) This tiring manœuvre is so rapidly effective that the pelvis can be lowered within a minute or two elevation of the legs can be continued Two first aid workers can raise all four limbs and the pelvis

Fig 30
First-aid treatment of shock hæmorrhage syndrome.
(*According to R K Hewat*)

Morphia and its derivatives—When given at a first aid post as a rule morphia should be given in small and if necessary repeated doses The fact that morphia has been administered and the amount should be noted by marking the patient with some prearranged symbol say on the forehead This is better than by an attached label which may be torn off In severe cases of shock the circulation may be so poor that morphia given subcutaneously is not carried to the central nervous system in reasonable time An almost immediate action can be produced by giving ¼ gr of morphia dissolved in 1 c c of sterile water intravenously A minute or two should be occupied in the injection

Application of heat—This can be done by obvious methods such as wrapping the patient in warmed blankets etc It will be part of the team clinical judgment to decide if and when operative treatment is necessary When the patients are numerous the resuscitation officer cannot be expected to do all the transfusions, and he must be allocated trained assistants no one can care for more than six profoundly shocked patients at a time A supply of sphygmomanometer cuffs that may be left in position on the patients' arms saves time and adds to efficiency

The time factor—In dealing with the injured the time factor is of the utmost importance Rapid evacuation from the scene of injury to a properly equipped hospital is of vital urgency It will be appreciated that the great difficulty is that there is no scientific method of estimating when the beneficial effects of resuscitation have reached their maximum If there was, the problem would be simple, as it is the surgeon must rely on clinical judgment

Once the patient is in hospital, by appropriate treatment secondary shock can be anticipated, and by timely and appropriate operation the almost inevitable toxæmia can be prevented This toxæmia depends upon the extent of tissue damage, the virulence of the infection and the time which has elapsed since the infliction of the wound It is not possible to fix the time limit for the performance of wound excision, but all surgeons of experience agree that it should not be more than eighteen hours from the time of the injury (see Chapter X)

The time factor may account for the great difference of opinion regarding the efficiency of our methods of treatment Many observers have found these methods profoundly disappointing For instance, Ball and Qvist state that morphia, the application of heat and plasma transfusion—in fact, all that we have to offer shocked air raid casualties—seems of little avail, the mortality remains at about 50 per cent On the other hand, as the result of two successive prolonged air raids, over 550 casualties were admitted into the hospital of an English city The surgeons in charge of these patients inclined to the view that in most instances intravenous medication was not even necessary, for a very high percentage of patients responded quickly to simpler methods of treatment The real explanation of these diametrically opposite views lies in the appreciation of the time factor When cases are admitted after a short, sharp "blitz" they arrive suffering from profound shock and the effects of blast In the series of 550 casualties quoted above it must be appreciated that the two air raids were prolonged ones It is more than likely that the really severely shocked patients never arrived at the treatment centres, they had succumbed before it was possible to transport them thither It is invidious to draw conclusions concerning groups of casualties unless the conditions under which the injuries are received are strictly comparable

ANÆSTHESIA IN RELATION TO SHOCK

It is absolutely contraindicated to administer a spinal anæsthetic to a wounded patient who is suffering from shock Now that blast is so much in evidence, and minor degrees are difficult to diagnose, especially in the presence of other more obvious injuries, there should be considerable trepidation about giving an inhalation anæsthetic Clarke and Kessell consider that the statement, "Gas and oxygen, combined with ether, if necessary, is the anæsthetic of choice," as made in the Medical Research Council War Memorandum on Wound Shock, is a dangerous one

During the Finnish war Pschenichnikov used local anæsthesia for all his cases With two operating tables in action he was able to compare the conditions of patients operated on under general and local anæsthetics When local anæsthesia was employed the patient often came out of the shocked condition while still on the operating table He further noted that the operating time was not appreciably lengthened by the use of local

Some modern resuscitation wards are equipped with oxygen pipes supplying each bed It is better to arrange oxygen administration units so that three or four patients can be treated from one supply (Fig 42) To have a larger series of beds fitted so that ten or more patients can be treated from one cylinder is inadvisable because should the resuscitation ward be put out of action the loss is irreparable for the time being Smaller mobile units can be wheeled to another part of the building

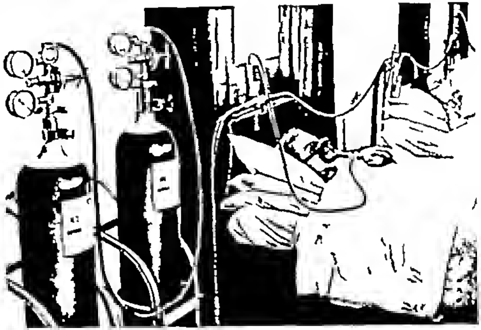

Fig 42

Continuous oxygen therapy Four patients receiving oxygen from one supply (*British Oxygen Co.*)

Pressor substances—In the shock associated with burns repeated intravenous injections of eucortone (Allen & Hanbury) have been reported upon favourably (Wilson) The dose of this extract of suprarenal cortex for a child is 1 c c every two hours and for an adult 2 c c every two hours There is no reason to believe that anything but good accrues from the exhibition of this or similar preparations in traumatic shock Desoxy corticosterone should be given an extended trial (Edwards)

Cardiac stimulants—Shock is not a condition primarily affecting the heart or the respiratory centre Cardiac stimulants certainly raise the blood pressure and increase the force of the heart beat for a time but it is doubtful whether any of these drugs are of real and lasting value It is difficult to dogmatize The surgeon faced with this perplexing clinical condition might argue that even if no good results from cardiac stimulants at any rate no great harm can be done and one must do something

With the life of the patient swinging in the balance even a small error in treatment may turn the scales against him. In the author s opinion it is better to abjure from all cardiac stimulants in the treatment of shock

The vascular system needs fluids only circulating fluid will give lasting benefit in shock The problem before us is to keep the fluid that is work in the resuscitation wards to have these folded in such a manner that they can be applied quickly and efficiently Hot drinks—sweetened tea is as good as anything—should be given Heat should also be applied by hot bottles, stoves can be placed in the vicinity of the bed or stretcher These methods must depend on the conveniences at hand One of the best methods of applying heat is by cradles fitted with electric light bulbs, for the temperature within the cradle can be controlled accurately

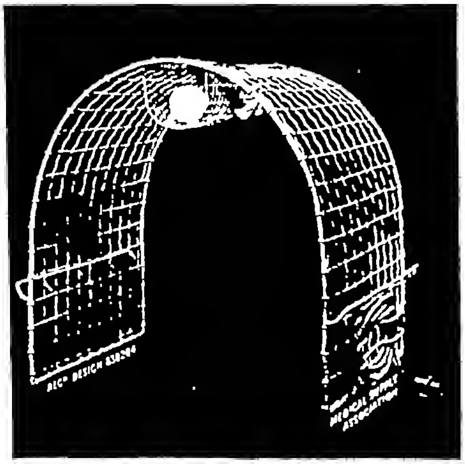

FIG 40

The Restor electrically heated resuscitation cage

The Restor type of electrically heated cage (Fig 40) made by the Medical Supply Association has proved very satisfactory Another excellent model is an all-metal cradle made by Phillips Lamps Ltd These cages and cradles should be sufficiently long to cover three-quarters of the individual, sufficiently wide to go over a stretcher and sufficiently high to allow the patient to turn over

Posture and bandaging—The raising of the foot of the bed aids the circulation in cases of primary shock when there is dilatation of the splanchnic area, and so also does bandaging of the extremities. It is difficult to understand how these methods can be of any value in secondary shock

The administration of fluids—In order to augment the loss of blood volume the circulating fluid must be increased As a first-aid measure, hot sweet tea has been found by experience to be beneficial In the profoundly shocked the intravenous administration of large quantities of plasma has proved better than any method yet devised, and is in keeping with our conception of the pathology of shock In the shock-hæmorrhage syndrome, blood transfusion is called for The whole subject of infusion and transfusion is discussed in the two succeeding chapters

Continuous oxygen therapy—Efficient oxygen administration may well be the determining factor in saving a desperate case It should be administered by a B L B mask (see Fig 36) In the absence of an efficient mask, Marriott suggests an ingenious makeshift improvized from a rubber association football bladder and a standard civilian respirator (Fig 41)

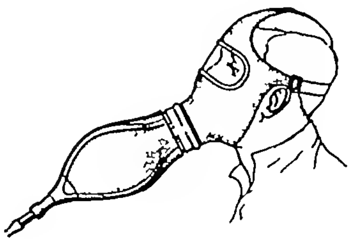

FIG 41

A respirator adapted as an oxygen mask (*After Marriott*)

The conversion from a respirator to an oxygen face piece can be achieved in a minute A hole is made in the pole of the football bladder remote from the inlet, by cutting off the terminal inch of the deflated, folded bladder The hole is then slipped over the canister of the respirator The junction is reinforced by moving forward the rubber band which secures the face piece to the canister, and the football bladder is connected directly to the tubing from the oxygen cylinder The oxygen should be turned on before the face piece is put on the patient, and the flow regulated so that the bladder is moderately distended during expiration administered in circulation We are a little nearer the solution of this problem than our forebears

Recording results of treatment—Kanaar has devised a resuscitation record card[1] (Fig 43) If such cards were filled in conscientiously there is little doubt that extremely valuable information regarding wounds shock and the best methods of treating the latter would be forthcoming

It would be better still if some central body such as the Medical Research Council supplied such cards and later correlated the results

[1] The cards can be obtained from G E Austin, 27 The Market Place Richmond, Yorks.

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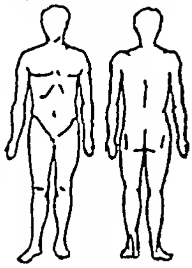
Resuscitation Records Card No

Name | Address
Age | Sex
Soldier s No | Rank | Unit
Approximate weight
Cause of Injury | Designation of medical unit
Date & time of injury | Morphine (Before ad mission) | Dose | Time
Date & time of admission | A T S units at
A G S units at

Section A * History | Injuries Sustained



* Add brief notes, where possible on condition and treatment before admission—e g dehydration cold pain, severe haemorrhage, sepsis (especially gas gangrene) morphine and chemotherapy

Section B Severity of Shock on Admission and during Treatment

Times									
B P									
Pulse rate									
Character of radial pulse									
Temperature									
Temperature of limbs to palpation									
Colour									
Respiratory rate									
Restlessness									
Hb %									
Addenda *									

* E.g coma, concussion, apathy, character of respiration dryness of tongue

Section C Treatment of Shock after Admission

1 Administration of Fluids

(a) Intravenous

Ref No of Bottle*	Time Start	Time End	Nature of Fluid	Reactions Notes

(b) Oral

(c) Rectal

* Containing 1 pint unless otherwise stated.

Section C (continued)

2 Morphine

Dose	Time

3 Chemotherapy

Drug	Dose	Time

Addenda (e g , oxygen, cortin, etc.)

Section D Operation

Anaesthetic | TIME Start | End

Procedures

Section E. Remarks and Summary *

Signed

Section F Later Notes

Date			
Hb %			
Dehydration			
Sepsis			

* E.g. factors tending to prolong shock summary of course and progress

FIG 43

quito type are ideal The only other essential special instrument is a pair of dissecting forceps with fine serrated points A pair of really fine-pointed scissors that cut at the points is a great advantage (Fig 45) The cannula (Fig 46) is a very important item Siggar's glass cannula is

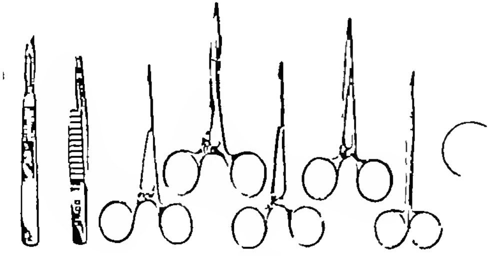


Fig 45

Instruments for cutting down upon a vein in order to tie in a cannula. The rather larger haemostat is used for clearing the vein from subcutaneous tissues in the manner shown in Fig 51

very serviceable The gold plated cannulæ will be found eminently suitable and I should like to call especial attention to the child's model for use when only small veins are available To be regularly in service a gold plated cannula must be replated from time to time and after use it is necessary to see that all blood and blood clot are removed from its lumen before it is put away

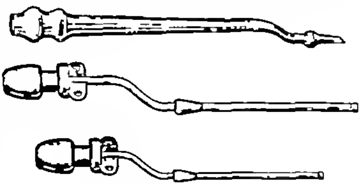


Fig 46

Vein cannulæ

A, Siggar's glass cannula.
B Hamilton Bailey's gold plated cannula.
C Hamilton Bailey's child's model.

Choice of a vein—The long saphenous vein the veins at the fold of the elbow and the external jugular provide all that is ever required By general consent the long saphenous vein is usually the most suitable for war casualties the principal reason being that the lower limb can be splinted securely which is such an obvious advantage I would urge however that this selection be not adopted as a mere routine Should it happen that the patient has been in bed for some time is elderly or is suffering from sepsis there is a possibility nay probability that some thrombosis has occurred in this part of the venous system Consequently in these types of patients the introduction of fluid into a vein of the leg may dislodge clot and cause pulmonary embolism

CHAPTER VI

CANNULIZATION FOR INFUSION AND TRANSFUSION

FOR a war surgeon there can be hardly a more important acquisition than to be able to tie a cannula into a vein of a collapsed patient expeditiously and effectively I say *tie a cannula* into a vein advisedly in those who need fluids most—patients suffering from shock and hæmorrhage—the veins are collapsed and expeditious entry with a hollow needle is, to say the least of it, problematical Even if such entry is effected, restlessness, transportation or lack of skilled attention too often result in the needle becoming displaced, instead of the patient receiving the fluid he needs so desperately, he gets a hæmatoma proportional to the size of the needle employed

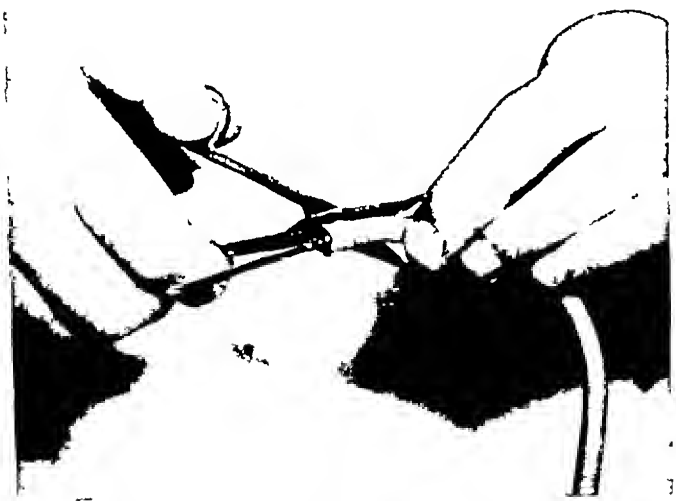


Fig 44
Cutting the needle off the tubing in order to substitute a cannula

In this connection let us examine a standard set Thousands of these have been distributed in order to infuse and transfuse the victims of modern warfare, many of whom suffer from a degree of collapse the like of which has seldom been encountered before Look at the needle supplied in this instance Even a super-expert in venipuncture could not hope to enter a vein of a collapsed casualty with such an instrument, its calibre suggests to me what a veterinary surgeon would select to enter the jugular vein of a horse in full fettle

In order to ensure reasonable success in replenishing the circulation of a collapsed patient there can be no question that our first duty is to amputate the needle from the tubing (Fig 44) and to substitute a cannula

TYING IN A CANNULA

Armamentarium—In every walk of life skilled technicians pride themselves on their tools and keep them in perfect order The tools for tying a cannula into a vein are extraordinarily few and simple, yet in the many hospitals in which I have worked I have observed that relatively large hæmostats and clumsy toothed dissecting forceps are put out for this delicate operation, and frequent bungling with these improper instruments ensues The essential equipment is three pairs of really delicate hæmostats—the so-called mostherewith The distal one is tied and its end caught in a hæmostat Traction on the proximal ligature will prevent loss of blood while the vein is opened The vein wall is picked up in dissecting forceps and with fine pointed scissors a triangular flap is raised The apex of the flap is grasped in a hæmostat

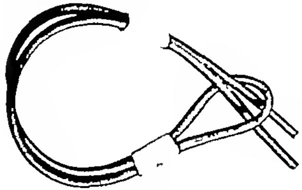


FIG 50
Self releasing vein tourniquet

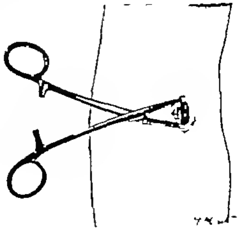


FIG 51
A small transverse incision has been made Method of displaying the vein by opening the jaws of a hæmostat

or by dissecting forceps (Fig 52) If it appears that there will be difficulty in inserting the cannula it is a good practice to place a hæmostat on each side of the incision in the vein (Fig 53) With this technique a cannula slightly larger than the vein can be inserted When the cannula (through which saline is now running) is within the lumen the proximal ligature encircling the vein and the nozzle within is tied It is essential to remember that the tourniquet must be released at this juncture Having cut the ligatures two skin sutures are used to close the incision about the cannula If the gold plated cannula has been employed a further stitch is used to anchor the cannula in position via the slots at the base Whatever fluid is to be administered in order to be certain that the apparatus is in working order it is advisable to allow ¼ pint of saline to gravitate into the vein in the first instance

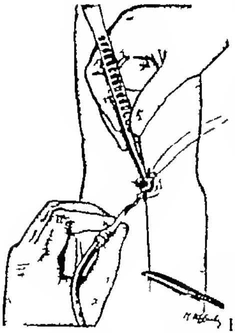


FIG 52
Insertion of a cannula into a vein.

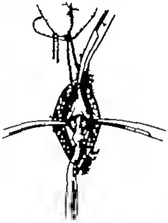


FIG 53
A good method of inserting a cannula into a small vein.
(*After J L. Keeley*)

When the internal saphenous vein has been used four pieces of strapping

It is desirable to refresh our memories on the surface anatomy of relevant portions of the veins referred to.

FIG. 47

The long saphenous vein, the site of election for cannulization

The LONG SAPHENOUS VEIN (Fig 47) is formed by the union of the medial end of the dorsal venous arch with the medial dorsal vein of the big toe It passes in front of the medial malleolus, and it is just above and in front of the medial malleolus that it should be exposed The vessel here lies rather more deeply than one is inclined to believe and it is accompanied by the long saphenous nerve

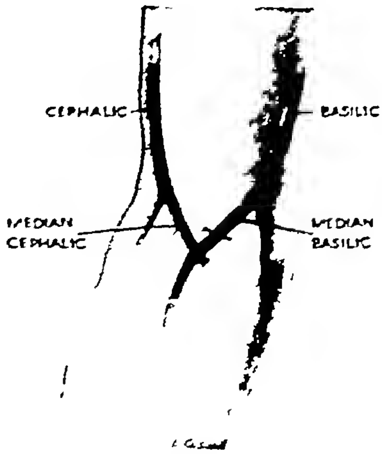


FIG 48

The median cephalic and median basilic veins

The MEDIAN CEPHALIC and the MEDIAN BASILIC VEINS (Fig 48) are both excellent radicles for cannulization The typical arrangement of veins at the fold of the elbow requires no description

The EXTERNAL JUGULAR VEIN (Fig 49) descends from a point just behind the angle of the jaw to the middle of the clavicle It is separated from the surface by the platysma muscle Its relation to the sternomastoid should be noted

Technique—In the case of the arm, the delicate efficient self-retaining tourniquet shown in Fig 50 made in a few moments from a length of ¼-in drainage tube and adhesive plaster is ideal for applying the necessary pressure A vein tourniquet being in place venous blood is milked towards the proposed site of exposure In a conscious patient the overlying skin is anæsthetized by injecting a few minims of 1 per cent. novocain A short transverse incision is made over the vein and the beak of a small hæmostat introduced into the wound and its jaws opened widely (Fig 51) If this manœuvre is carried out three or four times, the vein will be cleared from the subcutaneous tissues better than by a painstaking dissection and there is no fear of tearing even a delicate vein The entire circumference of the vein must be freed over a distance of about 1 cm. Two catgut sutures are passed beneath the vein There is no need to use an aneurysm needle the beak of the hæmostat is passed under the vein and the ligatures grasped

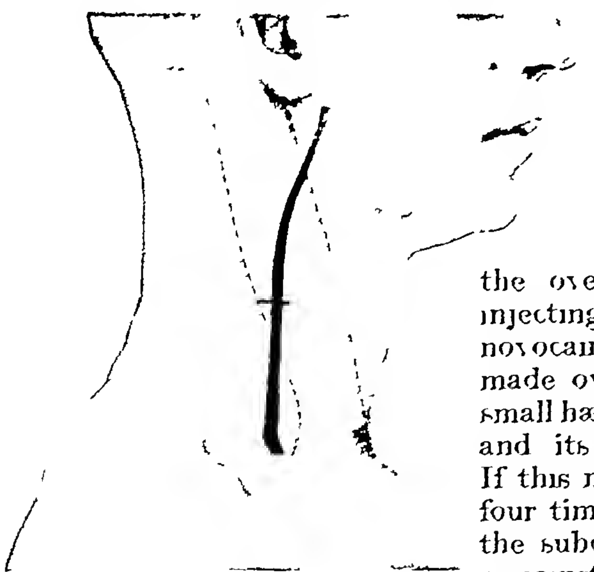


FIG 49

The external jugular the site of election for cannulization therewith The distal one is tied and its end caught in a hæmostat Traction on the proximal ligature will prevent loss of blood while the vein is opened The vein wall is picked up in dissecting forceps and with fine-pointed scissors a triangular flap is raised The apex of the flap is grasped in a hæmostat

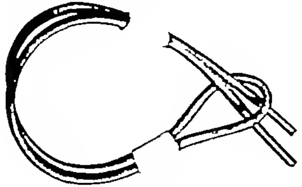


Fig 30
Self releasing vein tourniquet

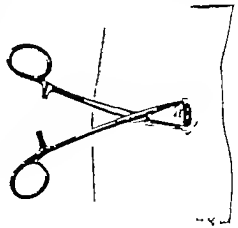


Fig 31
A small transverse incision has been made. Method of displaying the vein by opening the jaws of a hæmostat

or by dissecting forceps (Fig 52) If it appears that there will be difficulty in inserting the cannula it is a good practice to place a hæmostat on each side of the incision in the vein (Fig 53) With this technique a cannula slightly larger than the vein can be inserted When the cannula (through which saline is now running) is within the lumen the proximal ligature encircling the vein and the nozzle within is tied It is essential to remember that the tourniquet must be released at this juncture Having cut the ligatures two skin sutures are used to close the incision about the cannula If the gold plated cannula has been employed a further stitch is used to anchor the cannula in position via the slots at the base Whatever fluid is to be administered in order to be certain that the apparatus is in working order it is advisable to allow ¼ pint of saline to gravitate into the vein in the first instance

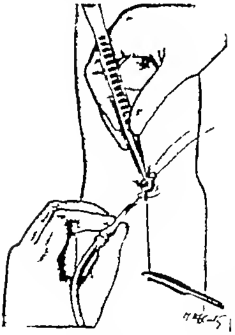


Fig 52
Insertion of a cannula into a vein.

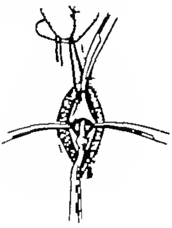


Fig 53
A good method of inserting a cannula into a small vein.
(After J L Keeley)

When the internal saphenous vein has been used four pieces of strapping are applied as shown in Fig 54 The limb is placed on a back splint with a foot-piece Alternatively, Thomas knee splint can be used The latter is a great advantage in ensuring immobilization of the limb when the patient is restless In the case of the arm either a Carr s splint or a plaster strip well padded with Gamgee with a turn around the wrist is eminently satisfactory If the arm is placed in the natural position it is far less arduous for the patient than the supinated position so commonly adopted (Fig 55)

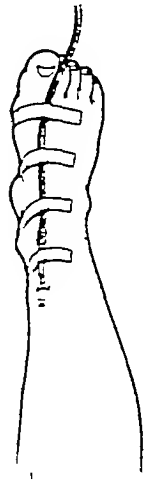


Fig 54
Method of securing the tubing to the foot (Edwards' method)

VENIPUNCTURE

When veins are small or there is a possibility of the needle within the vein becoming displaced transfusion and intravenous infusion should unquestionably be conducted through a tied-in cannula This does not imply that venipuncture has to be relegated to an insignificant backwater On the contrary the uses of venipuncture as a means of introducing fluids let alone for withdrawing blood are still very much in evidence

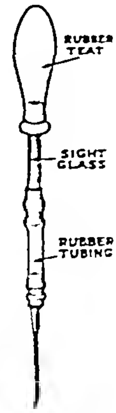


Fig 56
Edwards vein seeker

Edwards' vein seeker (Fig 56) is proving most useful and familiarity with this ingenious piece of apparatus is recommended The vein

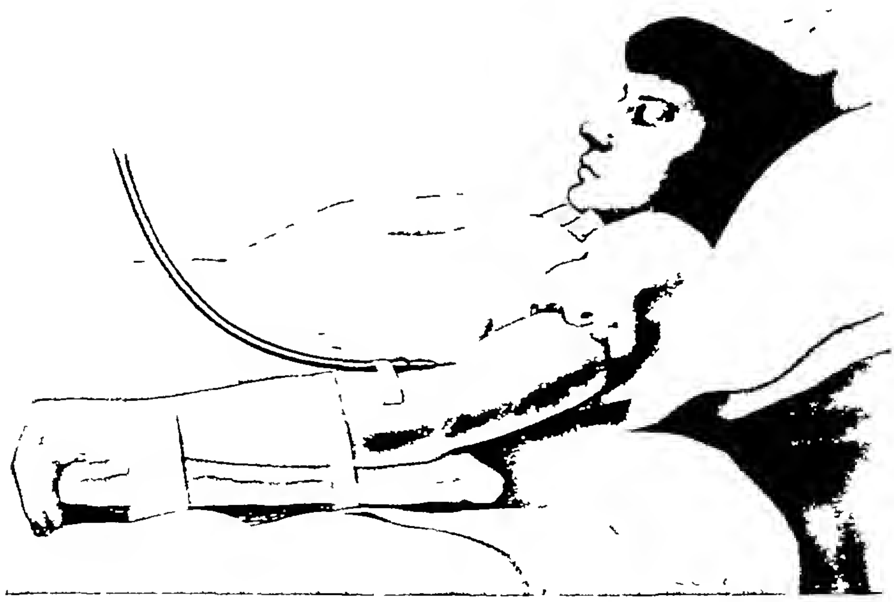


Fig 55
Arm in the position naturally assumed by the patient This is far more comfortable for continuous intravenous infusions than the usual supinated position
(*After J L Keeley*)

seeker is filled with sodium citrate solution (Fig. 57 (1)) It is 4 in. long, and this allows the butt-end of the needle to be held between the thumb and forefinger while the teat is compressed by the fourth and fifth digits against the hypothenar eminence (Fig 57 (2)) The teat now compressed is empty but the rest of the instrument is still filled with citrate solution The point of the needle is inserted under the skin where the vein is suspected and the pressure on the teat released (Fig 57 (3)) The teat remains collapsed until a vein is entered (Fig 57 (4)) when the negative pressure within the teat draws blood into the instrument When blood appears in the glass tube the whole instrument is fixed in position by

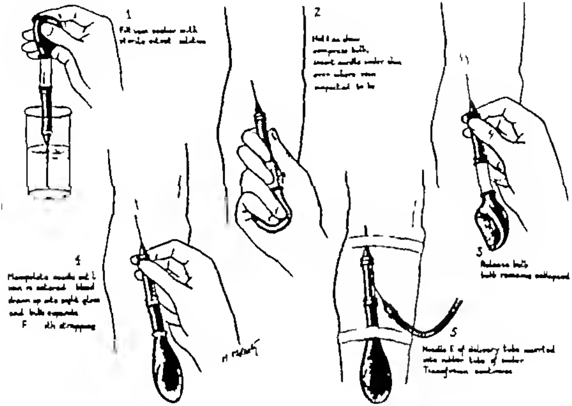


Fig 57
The technique of Edwards vein seeker

two strips of adhesive plaster (Fig 57 (5)) By sterilizing the rubber tubing between the needle and the sight glass with spirit the vein seeker becomes virtually a large vein on the surface and into it blood or any other intra venous injection can be gravitated or injected at will

THE CORPORA CAVERNOSA AS A SITE FOR TRANSFUSION

Using a large hollow needle a corpus cavernosum is entered either from the lateral aspect or from the dorsum just to one side of the dorsal vein Plasma or citrated blood can be introduced into the cavernous space but a syringe is required transfusion by gravitation is too slow The *fascia* (Scarpa s) surrounding the body of the penis ensures that very little swelling of the organ occurs If the gross anatomy of the cross-section of the penis (Fig 58) is borne in mind it is impossible to injure the urethra or the dorsal vein As a rule the dorsal vein becomes distended as the transfusion progresses are applied as shown in Fig 54 The limb is placed on a back splint with a foot-piece Alternatively, Thomas' knee splint can be used The latter is a great advantage in ensuring immobilization of the limb when the patient is restless In the case of the arm, either a Carr's splint or a plaster strip well padded with Gamgee with a turn around the wrist is eminently satisfactory If the arm is placed in the natural position it is far less arduous for the patient than the supinated position so commonly adopted (Fig 55)

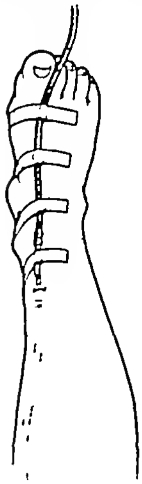


Fig 54
Method of securing the tubing to the foot (Edwards' method)

VENIPUNCTURE

When veins are small or there is a possibility of the needle within the vein becoming displaced transfusion and intravenous infusion should unquestionably be conducted through a tied-in cannula This does not imply that venipuncture has to be relegated to an insignificant backwater On the contrary, the uses of venipuncture as a means of introducing fluids, let alone for withdrawing blood, are still very much in evidence

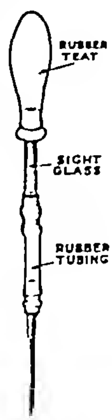


Fig 56
Edwards' vein seeker

Edwards' vein seeker (Fig 56) is proving most useful, and familiarity with this ingenious piece of apparatus is recommended The vein

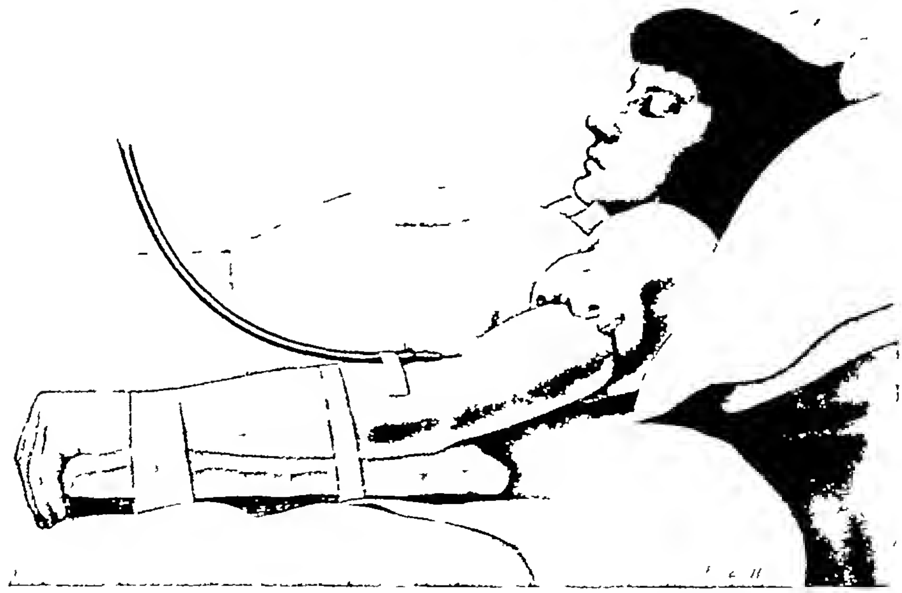


Fig 55
Arm in the position naturally assumed by the patient This is far more comfortable for continuous intravenous infusions than the usual supinated position
(*After J L Keeley*)

seeker is filled with sodium citrate solution (Fig 57 (1)) It is 4 in. long, and this allows the butt-end of the needle to be held between the thumb and forefinger while the teat is compressed by the fourth and inner side In both instances the point of the needle is directed towards the diaphysis When the flow into the marrow is satisfactory the splinted leg should be raised slightly

If the infiltration with local anesthetic has been

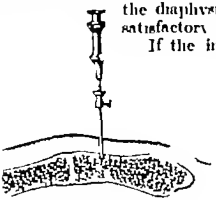


Fig 59

Piercing the periosteum of the manubrium.

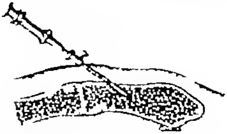


Fig 60

The bone marrow entered Note the angle of the needle

done thoroughly penetration of the bone by the marrow needle causes but little discomfort In most instances the fluid gravitates into the marrow very slowly at first but within ten to fifteen minutes it is somewhat accelerated By means of a syringe it is possible to inject over 40 c c per

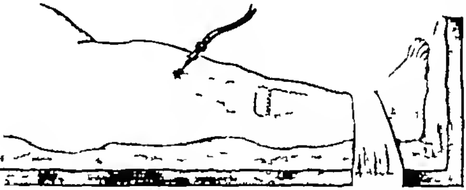


Fig 61

Bone-marrow infusion into the lower end of the femur of a child under three years of age The needle is usually inserted nearer the epiphysis

minute intrasternally but such rapid injections are only justified in desperate cases of shock An average rate of flow into the manubrium by gravity is 3½ c c per minute Tocantins and O Neill have infused successfully by this route citrated blood citrated plasma 5 per cent glucose solution and normal saline

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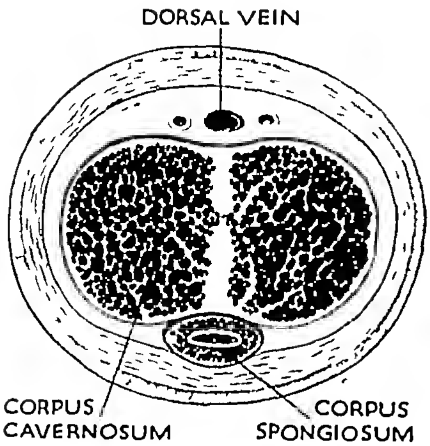

Fig 58

If the needle is inserted into the antero lateral portion of the corpus cavernosum, the urethra and dorsal vessels are not endangered

A corpus cavernosum should not be employed as a site for infusion of saline or glucose, because of a risk of cavernositis, but for the reception of plasma and citrated blood it has proved to be regularly satisfactory (R E Strain)

INFUSION INTO BONE MARROW

There are occasions when no vein is available, it may be that every suitable vein has been utilized already, or the patient is a young child Under such circumstances marrow of a bone may prove a welcome avenue for the reception of fluids

In the adult the best bone to select is the manubrium or the body of the sternum midway between the angle of Louis and the xiphisternum The skin, subcutaneous tissues and underlying periosteum are infiltrated with novocain The bone-marrow needle (Fig 58 A) is inserted vertically with the bevel upwards, and the periosteum is pierced (Fig 59) with a to-and-fro motion The needle is then tilted until it makes an angle of about 30° with the surface of the skin, and continuing the semicircular to-and-fro movement, the anterior plate of the sternum is penetrated (Fig 60) There is a sensation of diminished resistance when the marrow is entered The stilette is removed from the inner needle and a syringe containing about 1 c c of saline is attached If the point of the needle is within the marrow cavity, blood-marrow mixture will be aspirated with little effort The inner needle is removed with the syringe, and the former is flushed through with saline and reinserted, while alternately aspirating and injecting saline through it The object of this manœuvre is to remove air from the lumen of the outer needle One or two cubic centimetres of citrate solution is injected into the marrow slowly Immediately afterwards the inner needle is removed, and the adaptor connecting it with the saline apparatus is swiftly and securely attached to the outer needle

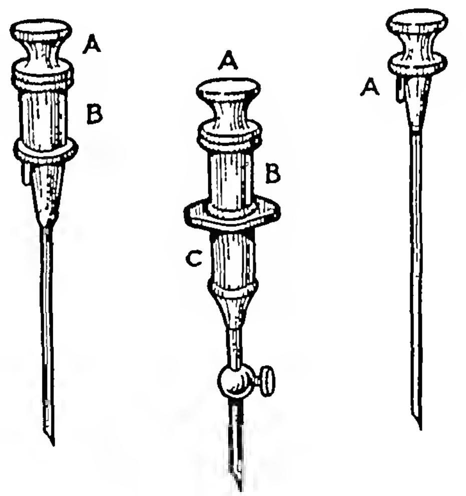

Fig 58 A

The bone marrow needle

A, Stilette

A-B, Internal needle (gauge 18) with stilette in place

A-B-C, Stilette, internal needle and external needle (gauge 15) with guard

(*Made by Down Bros*)

In young children the lower end of the femur or upper end of the tibia is utilized When the femur is utilized, the needle is inserted ½ in above the external condyle (Fig 61) In the case of the tibia, entry is effected ½ in below the proximal end of the subcutaneous border, a little to the

Any plasma which contains evidence of hæmolysis of red cells should not be used if the coloration is more than the faintest pink

The preparation of preserved serum—Serum gives less trouble in filtering and storing than does plasma as there is no deposition of fibrin. It has been reported that it also gives rise to more reactions, but further experience has not confirmed this.

Serum is prepared by allowing the blood to clot leaving it twenty four hours for the clot to retract, and then pouring off or withdrawing the separated serum. It may also be prepared artificially by adding 20 c.c. of 8 per cent calcium chloride to 1 litre of plasma, shaking with glass beads, and then drawing off the supernatant serum from the clot which has been formed (Clegg and Dible) The fibrinogen which is present in plasma and absent in serum has little effect on the osmotic pressure and from this point of view there is little to choose between serum and plasma.

The preparation of dried plasma and serum—Drying may be undertaken by evaporating the water from the serum in the frozen state under a high vacuum This produces a yellowish white powder which dissolves again on addition of distilled water (Greaves and Adair; Flosdorf and Mudd) Plasma may be dried similarly or by desiccation at 37 to 55 C. under low vacuum (Edwards, Kay and Davie).

Dried serum is distributed as a powder dried on the walls of the container which is also used as the bottle for administration. Pyrogen free distilled water is poured into the bottle, up to the mark given for the amount of dried material contained therein, and the whole shaken vigorously for a few minutes. Complete solution will occur and it is then administered in the ordinary way Reconstituted dried serum should be given immediately after preparation, as contamination is likely to occur during the process of adding the distilled water and it is important that no toxin formation should occur

Dried plasma has some advantages from the storage point of view and it is possible that it may keep longer than the liquid Nevertheless, experience of liquid plasma has shown that so far no definite time can be given as to when it becomes unsuitable for administration. Certainly the use of liquid plasma a year old is not associated with untoward effects. The dried plasma is, however less likely to culture organisms and is probably safer from this aspect, but there is no actual diminution in bulk for transport purposes unless a suitable supply of pyrogen-free distilled water for reconstitution is available at the place of administration.

THE RATIONALE OF PLASMA INFUSION

Maintenance of the blood volume is essential to life only if the blood volume is adequate can oxygenation of the essential organs and vital centres be maintained Blood plasma contains electrolytes (sodium chloride sugar etc) and protein bodies—albumin globulin and fibrinogen—collectively called plasma protein

Increase in blood electrolytes as for example by the administration of intravenous saline increases the blood volume but because electrolytes pass rapidly into the tissue spaces and/or are excreted by the kidneys the effect of increasing blood volume by saline infusion is only very temporary

Normally the protein constituents of the plasma neither pass into the tissue spaces nor are they excreted in the urine and so by administration of plasma the osmotic tide from the tissue fluid to the blood stream rises and the blood volume increases correspondingly

INDICATIONS

Shock—As a result of the peripheral vascular collapse the blood pressure falls, oxygenation of the cells of the capillary walls is interfered with and exudation of fluid occurs This exudation consists at first of fluid containing electrolytes but later it becomes rich in plasma protein

Hæmorrhage—The loss of red cells is a far less serious matter than a corresponding loss of plasma proteins and electrolytes *If as much as 30 per cent* of the patient's blood is lost the remaining 70 per cent contains

CHAPTER VII

INFUSION OF BLOOD SUBSTITUTES

(A) PLASMA INFUSION

THE **preparation of preserved plasma**—As plasma forms an ideal culture medium for organisms it is imperative that the strictest asepsis be maintained in its preparation A rather dilute plasma results when the M R C citrate solution is employed By using 3 8 per cent citrate solution, 1 part to 9 parts of blood, a plasma having a higher percentage of protein is obtained, and this is probably somewhat more effective in action

One pint of plasma can usually be extracted from 2 pints of blood Plasma from all groups can be mixed together, and the resulting fluid is practically free from agglutinating tendencies, this is due to a mutual suppression of agglutinins It is on this account that grouping of the recipient is unnecessary and untoward reactions are so rare after the infusion even of a very large quantity of plasma

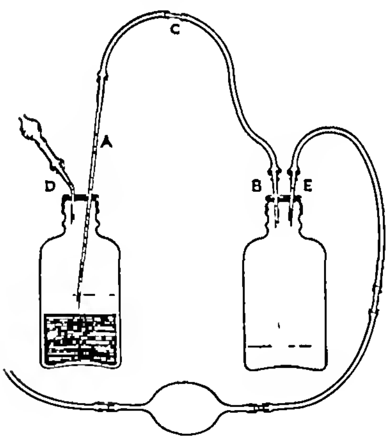

FIG 62

Method of removing plasma from bottles of stored blood

The simplest method of preparing plasma is by withdrawing blood into sodium citrate solution, as for stored blood, allowing it to stand for four to seven days, and then collecting the supernatant plasma Bottles of bank blood which have been stored for longer than seven days should not be used for blood transfusion, they can be used as a source for plasma Blood may also be drawn for the designed purpose of plasma production Such bottles of blood must be allowed to stand from five to seven days, so that "settling down" of the red cells can occur Centrifuging of bottled blood has also been employed, but this requires expensive apparatus The "packed" cells which remain may be further utilized (see p 79)

Supernatant plasma is drained off by suction through a fine needle into a sterile bottle (Fig 62) 250 to 300 c c of plasma can be withdrawn from 1 pint of citrated blood

In the large scale preparation of plasma the plasma is withdrawn from the settled red cells by suction into containers The resulting fluid may not be totally clear of red cells but it is passed through a wood-pulp filter which removes the fat and remaining erythrocytes It is then filtered through a multiple Seitz filter which removes all organisms After being subjected to these various processes the plasma is absolutely clear It is then bottled, allowed to stand at room temperature for forty-eight hours and then cultured, if the culture is negative it is ready for use

It is desirable to know by which process a given bottle of plasma has been prepared

FILTERED PLASMA should be stored at room temperature, for cooling in a refrigerator tends to cause precipitation of fibrin Cloudiness in *filtered* plasma suggests that infection has occurred

NON-FILTERED PLASMA should be stored in a refrigerator Cloudiness in many instances is due to the presence of fat globules operating theatre This would indicate that the blood volume is approaching normal and only under these conditions is the patient best able to withstand the anæsthetic and the operative procedure

Attention has been drawn in Chapter V to the patient who is obviously suffering from shock and yet registers a comparatively normal blood pressure

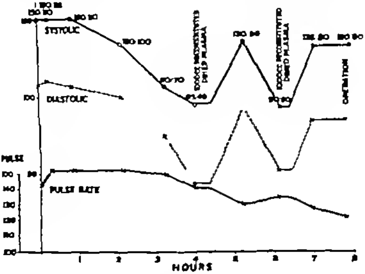

FIG 63

Woman aged 30 Admitted to *Liverpool Royal Infirmary* with third-degree burns covering one third of body surface

This case demonstrates well the following points —

1 There is a high blood pressure on admission, although clinically the patient was shocked.
2 There is a rapid fall of blood pressure during the next four hours despite warmth and fluids by mouth.
3. The response to plasma therapy—in this case reconstituted dried plasma (Edwards, Kay and Davie)
4 1 000 c.c of plasma was not enough to maintain the blood pressure and a second 1 000 c.c. had to be administered.

After seven hours the patient had a sustained blood pressure and was suitable for the administration of a general anæsthetic and coagulative treatment of the burns.

Convalescence was uneventful.

(Case under the care of Mr W M Beattie, F R C.S)

Such cases should be infused with plasma from the beginning if this is done the eventual fall of blood pressure which is often sudden and severe is minimized or even prevented (Fig 63)

Plasma administration if commenced in the resuscitation ward should be continued during the operation as a slow drip and speeded up if there is any loss of blood The drip should continue until the blood pressure has stabilized itself Intravenous cardiac stimulants may be given by injection through the tube The amount of plasma needed in severe cases of shock may be very considerable 6 8 or 10 pints are commonly necessary sufficient erythrocytes to maintain life, providing the blood volume is restored and maintained For reasons given it will be understood that a solution of electrolytes can *restore*, but the restoration will only be *maintained* if sufficient plasma proteins are introduced into the circulating fluid Pallor of a wounded individual is in most cases not an indication for blood transfusion, it is an indication for plasma transfusion The indication for blood as opposed to plasma transfusion is a hæmoglobin concentration of under 50 per cent

Burns and wounds involving extensive loss of skin—Burns, in particular result in exudation of plasma elements into the tissues and from the surface As a result of this exudation there is in the capillaries a high concentration of red cells which may give a capillary count of 8 to 9 million cells per cubic millimetre The administration of blood to such cases in sufficient quantity to restore the blood volume is contraindicated because it results in polycythæmia with increased viscosity of the blood and a lowered circulation time Plasma is the rational fluid to introduce into the circulation

Hypoproteinæmia—The normal plasma protein level is 6 5 to 9 gm per 100 c c of blood, and any level found below this figure can be considered as hypoproteinæmia This condition tends to occur in the presence of long-continued sepsis The fluid constituent of pus contains between 4 to 6 gm of plasma protein per 100 c c , and where there has been an extensive discharge, for example in large septic wounds and empyemata, the loss of plasma protein is such that the reserves in the body are used up and the level in the blood falls This condition is indicated by the following signs firstly, there is interference with the healing of the wound itself and fibroblast formation is slowed up , secondly, if the plasma protein level falls below 6 gm there is a tendency to œdema, which is seen at the site of injury, in the back, buttocks and ankles, and as pulmonary œdema and effusions into serous cavities , thirdly, if the condition persists for long enough, amyloid disease sets in Such cases may be treated by the giving of plasma intravenously in the acute stage, to be followed later by a high protein diet

TECHNIQUE OF ADMINISTRATION

Plasma is infused through a standard gravity transfusion apparatus fitted with a filter

Before administration, plasma should be warmed to room temperature The average rate of administration is about 500 c c in twenty minutes, but if the degree of shock is severe it is better to give it more quickly Once the fall in pressure has been remedied, the contents of succeeding bottles of plasma can be given slowly, *e g* , taking one to two hours over each bottle In patients moribund from shock the forced administration of plasma through two or three cannulæ inserted into different veins is worth trying By this means 2 or 3 litres of plasma can be given in half an hour Perhaps only by this method can rapid exudation of fluid from the capillaries to the tissue spaces be overtaken The danger of grossly overloading the right side of an already labouring anoxæmic heart must be taken into consideration nevertheless, unexpected recovery has followed this expedient often enough to warrant its being recommended

THE RÔLE OF PLASMA INFUSION IN RESUSCITATION

Every injured patient with a systolic blood pressure below 90 mm of mercury should receive plasma infusion Unless there is some reason to the contrary the patient should go on receiving plasma until the systolic pressure is at least 110 mm of mercury before being transferred to the

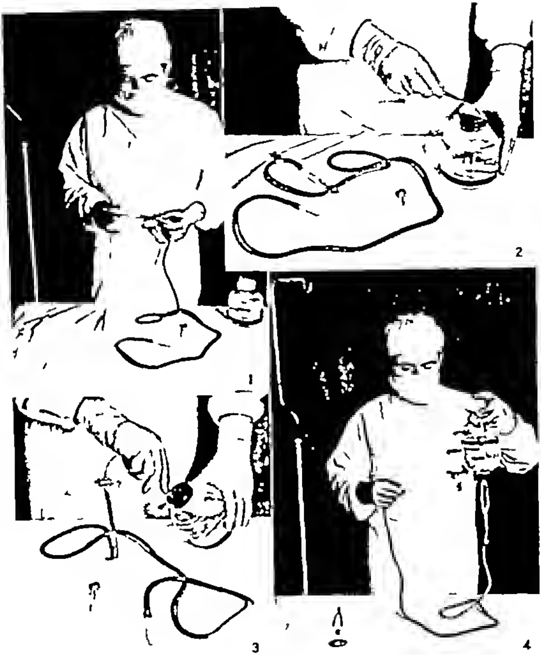

Fig 64

Assembling a Vacoliter

1 The apparatus is taken out of its sterile package
2 The metal cap is removed. On lifting off the underlying rubber disc two holes are seen in the stopper
3 The butt end of the glass interceptor is plugged firmly into the hole designated by an arrow
4 The Vacoliter is then inverted and hung on a stand.

(B) SALINE INFUSIONS

Under this heading are included principles relating to the infusion of 5 per cent glucose and isotonic sodium sulphate as well as normal saline

Over and over again to my certain knowledge intravenous saline particularly continuous intravenous saline, has proved a veritable breath of life, yet I have met pathologists who from their experience in the post-mortem room, are equally convinced that it has been an agent of death , the patient was literally drowned, they say So it comes about that unless intravenous saline is used with due care and with the intelligence to be expected of anyone with a reasonable physiological training, it is far better to employ the less certain but more fool-proof rectal or intramuscular routes

There are but two governing principles, and if these are observed meticulously they spell success, but if neglected through ignorance or carelessness they even more certainly spell disaster

1 The amount of fluid introduced into the circulation must be measured and its disposal accounted for

2 Fluid introduced directly into the circulation must be absolutely free from live or dead bacteria

1 Unless a balance-sheet is made up every twenty-four hours we have no check upon the patient's requirements I am definitely of the opinion that without a balance-sheet intravenous saline should never be continued for more than twenty-four hours

CONTINUOUS INTRAVENOUS SALINE BALANCE-SHEET

Patient's Name ______

24 hours ending	INTAKE	OUTPUT	
______ 19			
INTRAVENOUSLY —		URINE {S G __ a m / S G p m}	pts
* @__ drops per minute	pts	Vomitus	pts
* @__ ,, ,, ,,	pts	Normally 1½ pints { Fæces	pts
@__ ,, ,, ,,	pts	Sweating and lungs— say	pts
BY MOUTH			
Total	______	Total	______
GLUCOSE —			
5% solution (*allow 30 grams = 120 calories for each pint*) ______	calories		

* 50 drops per minute = 6 pints in 24 hours
* 30 ,, ,, ,, = $3\frac{3}{5}$,, ,,

When tarnished, gold-plated needles and cannulæ need replating thoroughly to determine the presence or absence of organic heart disease. In its presence, regardless of the state of compensation, fluids must be (1) given in small volume, (2) isotonic in nature, and (3) above all, must be administered slowly (Fig. 66). The patient without heart failure will tolerate fluids in amounts up to 3,000 c.c. a day even in the absence of dehydration. The main safeguard is an examination of the cardio-vascular system, and nothing more than a careful bedside study is necessary (F. D. Murphy).

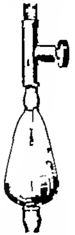

Fig. 66.

Hamilton Bailey interceptor. Very accurate dosage is possible with this model. Suitable for all blood substitutes, it is not recommended for blood (see p. 70).

CONTINUOUS INTRAMUSCULAR INFUSION[1]

When circumstances do not permit the administration of intravenous saline under the conditions of physiological control emphasized above, it is better to use the intramuscular route, for when fluid is given intramuscularly the danger of pulmonary œdema is remote. If more fluid is administered than can be absorbed, it causes local œdema. This route for administration of fluid, therefore, offers some advantages. The best site for the injection is the external side of the middle third of the thigh (Fig. 67). Bilimoria and Dunlop's needle with its adjustable shield (Fig. 68) is an asset. The needle is inserted nearly down to the bone, when the adjustable shield is fixed by turning the screw, making further penetration impossible. It is a good practice to insert the needle through a piece of sterile gauze which comes to lie between the shield and the skin. Once the needle is in place satisfactorily, it can be kept in position by adhesive plaster placed over the shield. A rate of about 40 drops a minute is suitable for most adults in need of fluid. When both thighs are used, a Y-shaped glass connection is interposed in the tubing leading from the flask. Each tube leading from the Y-shaped connection should possess an interceptor so that the flow to each thigh can be regulated.

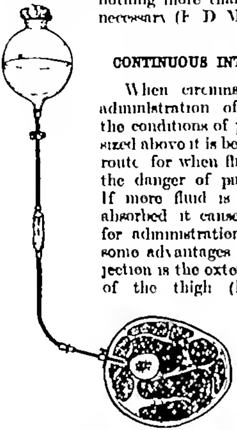

Fig. 67.

Continuous intramuscular administration of fluid in the lateral aspect of the middle third of the thigh.

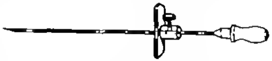

Fig. 68.

Bilimoria and Dunlop's needle for intramuscular administration of fluid. (*Made by Messrs. Thackray.*)

[1] Only saline or saline and glucose must be given by this route.

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There is absolutely no difficulty in making up this balance-sheet and in order to save trouble and time spent in clerical work pads of fifty can be obtained from the Genito-Urinary Manufacturing Co at the modest price of sixpence each In spite of this labour-saving process I find it necessary to be for ever vigilant in seeing that the correct making up of the balance-sheet is carried out

2 In a dire emergency, under extenuating circumstances, a pint or more of saline can be given as a massive single dose via a boiled funnel, tube and cannula Even under these circumstances tablets of salt or salt itself should not be employed if the truly sterile capsules of concentrated saline are available as they should be

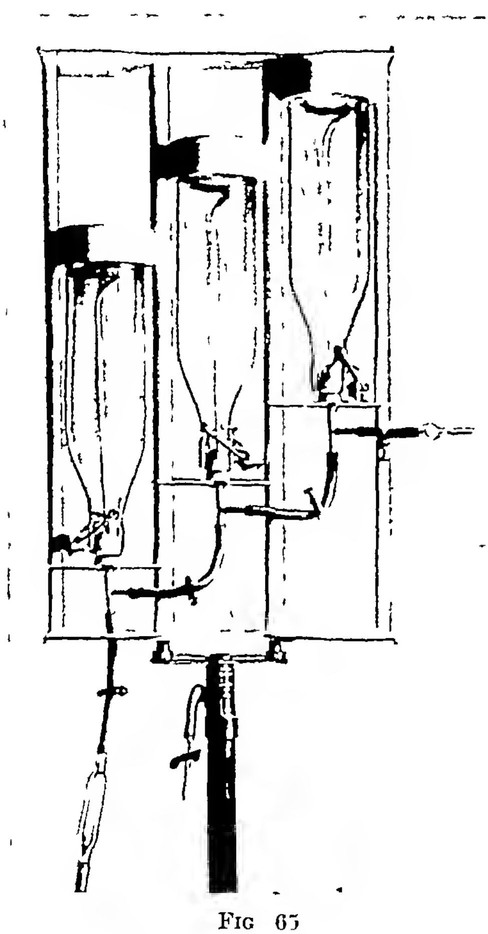

Fig 63

Crookes' continuous flow infusion unit

When it comes to administering intravenous saline continuously the question of sterility of the apparatus and the freedom of the solution from even dead bacteria does not arise in a work of this character Unless the surgeon is working in a large hospital, which in times of peace manufactured its own intravenous solution successfully it is not justifiable to improvise these arrangements Only one of several commercial products the sterility and freedom of dead bacteria of which can be guaranteed should be used Of these, the Vacoliter is best known The apparatus (Fig 64) is extremely simple to assemble

To prevent air collecting in the tubing the latter is coiled around the hand and held above the level of the interceptor before the clamp compressing the tube is released

Crookes' continuous flow infusion unit (Fig 63) is very efficient and has the advantage of being able to be replenished *ad libitum* without cessation of the flow Full directions for its use are supplied with the apparatus

Isotonic sodium sulphate solution can be obtained in Vacoliters Time and again I have had reason to marvel at the diuretic properties of this solution in cases of non-obstructive anuria and oliguria The same careful observation of intake and output must be rigorously followed when employing this solution

Summarizing It would be an unusual experience in therapeutics if enthusiasm for a good remedy did not at times lead to its abuse There is no test that will enable us to determine beforehand whether the patient will respond favourably to fluid therapy Every patient should be examined

CHAPTER VIII

BLOOD TRANSFUSION

BLOOD GROUPING

THE symptoms and consequences referable to incompatibility depend so far as is known upon agglutination of red cells in the circulation of the recipient. Agglutination of the red cells is due to the action of naturally occurring agglutinins in the plasma coming into contact in effective concentration with red cells containing agglutinable factors or agglutinogens upon which they are capable of acting

The presence in or absence from the red cells of these agglutinogens, and the presence in or absence from the plasma or its serum of the agglutinins determines into which of the four blood groups any given blood will fall

The agglutinogens are two in number and are referred to as A and B The agglutinins capable of acting upon them are referred to as anti A and anti B or a and β respectively Agglutinogens and agglutinins are reciprocals that is to say the agglutinins capable of acting upon the red cells of any given blood never occur in the plasma in which those cells are naturally suspended Conversely in the absence of these agglutinogens the homologous agglutinins will be present in the plasma

THE FOUR BLOOD GROUPS

The constitution of the four blood groups may be represented thus —

Plasma and Serum Agglutinins	Red Cells Agglutinogens	Group Nomenclature	
		Moss.	International.
Absent	AB	I	AB
Anti B	A	II	A
Anti A	B	III	B
Anti A and B	Absent	IV	O

It will be evident from the above that the determination of the group of any given blood may be made either by the use of serum or of red cells of known groups A (II) and B (III) In practice it is convenient and customary to use only sera of known groups A and B for this purpose

For the determination sera of groups A (II) and B (III) are brought into contact with a suitable emulsion of the red cells of the blood to be tested This may be done either in agglutination tubes or on plain slides The latter method is the quicker and more convenient and will be the only one described

Technique of blood grouping—In performing the test the red cells of the blood to be examined do not require to be separated from their plasma it is essential however that the blood be diluted As a diluent normal saline is perfectly satisfactory 3 5 per cent sodium citrate or any of the anticoagulant fluids used for purposes of blood transfusion are equally suitable Within wide limits the degree of dilution does not matter greatly two or three drops of blood withdrawn by a finger prick into about 2 c c of the diluent produces a satisfactory emulsion

Two microscope slides are used for each blood to be tested or if

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that it belongs to group O (IV) The appearance of the slides with the interpretation of the results is shown in Fig 69

In case either the agglutinin titre of the test serum or the agglutinogen content of the red cells to be tested, or both happens to be low the agglutination reaction may not be visible to the naked eye it is therefore advisable in all cases where agglutination is not so visible to confirm its absence either with a hand lens or the low power of the microscope after the preparation has stood with occasional agitation for about twenty minutes

"DIRECT MATCHING"

The results of an incompatible transfusion may be so disastrous that except in cases of extreme urgency it is inadvisable to rely upon the results of grouping alone Always when possible compatibility should be confirmed by matching which consists in bringing the actual serum of the recipient into contact with the red cells of the proposed donor For this purpose it is necessary to withdraw by venipuncture 2 or 3 c c of the blood of the proposed recipient to allow it to clot and to separate off the serum Centrifugalization considerably expedites this process but under the most favourable circumstances it cannot be carried out in under half an hour Having obtained a specimen of the recipient s serum it is tested against the donor s corpuscles in exactly the same way as has been described

Direct matching is essential when stored blood is used The group assigned to stored blood depends upon the result of the test made upon the donor when he or she was enrolled in the service There is no possibility of a change of group in the meantime but there are inevitable possibilities of clerical error

UNIVERSAL DONORS

It was pointed out above that incompatibility depends upon the agglutination of red cells in the circulation of the recipient In the infusion of blood it is customary to consider only the possibility of the agglutination of the red cells of the donor by the plasma of the recipient It is justifiably assumed that such agglutinins capable of acting upon the red cells of the recipient as may be present in the infused blood will be so much diluted by the plasma of the recipient that their titre will fall below effective concentration On this account the blood of group O (IV) the red cells of which contain no agglutinogens and are therefore inagglutinable by either of the plasma agglutinins is regarded as suitable for infusion into members of any of the four blood groups Members of this group are therefore frequently referred to as Universal Donors and blood of this group is now stored in large amounts with a view to its infusion into members of any blood group

So long as the amount of blood given does not greatly exceed one pint this use of Universal Donor blood regardless of the group of the recipient is probably reasonably safe It must be remembered, however that if a large amount of blood of group O (IV) be infused or if the recipient has suffered severe loss of blood or particularly in the face of a combination of these two circumstances the dilution of the agglutinins of the infused blood may not be sufficient to inhibit their action On this account it is preferred, the examination may be made upon a white porcelain tile The slides or the tile are marked clearly beforehand "A" or "II" and "B" or "III" On the slides are placed two drops of the appropriate grouping serum, a similar number of drops of the emulsion of red cells to be tested is dropped upon the serum and the red cells and serum mixed thoroughly

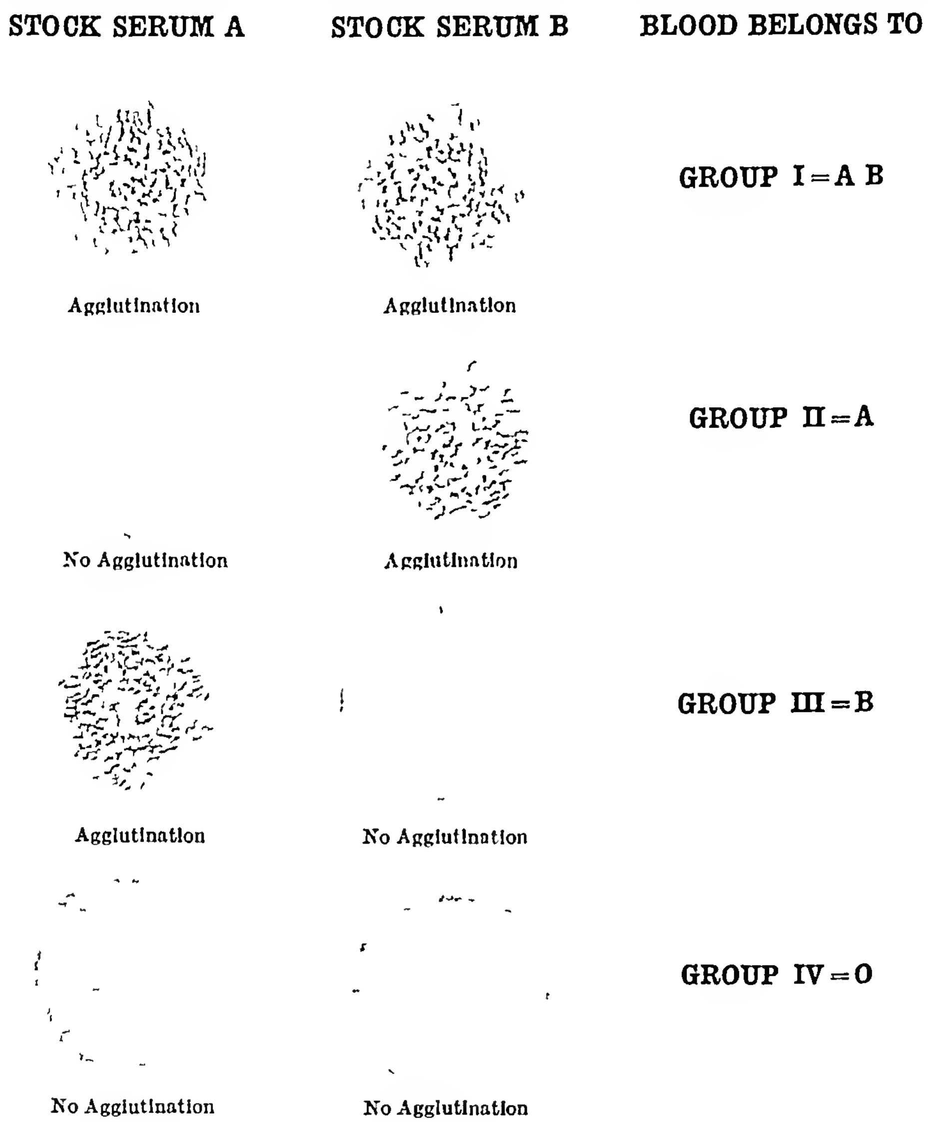


Fig 69

Blood grouping The result obtained in each of the four groups is shown (colour photograph)

with a platinum loop or a splinter of wood After standing for from five to ten minutes, the slides are rocked gently, if the grouping serum is of good titre, agglutination will be visible at once to the naked eye Agglutination of red cells by both sera indicates the presence of agglutinogens A and B in the red cells, and therefore that the blood belongs to group AB (I), agglutination by the B serum alone indicates that the blood belongs to group A (II), by the A serum alone that it belongs to Group B (III), and by neither blood pressure Usually a pressure of 70 to 80 mm Hg is satisfactory The surgeon then scrubs up and the skin in the antecubital fossa is sterilized with spirit or ether and the area draped with sterile towels Some citrate solution is run through to prevent clotting in the tube and needle (Fig 71) As the last drops are ejected from the syringe the end of the tubing is clamped with a small hæmostat

Fig 71

Citrate solution is run through the tube and needle This precaution obviates clotting therein.

A few minims of 1 per cent novocain are then injected just to one side of an appropriate vein and a small nick is made in the skin with the point of the scalpel The needle is then thrust beneath the skin through this small incision and then into the vein The hæmostat is released and the blood allowed to flow through the tubing into the flask While the blood is flowing the flask is rotated gently in a bowl containing water at body temperature to ensure thorough mixing of the blood and citrate This movement is carried out by a nurse while the surgeon s attention is directed to keeping the needle in position When the requisite amount of blood has been collected the sphygmomanometer is deflated and removed The needle is then withdrawn and firm pressure applied to the site of venipuncture After a bandage has been applied the donor is told to attend on the following day for an examination of the arm

Fig 72

E.M.S bottle adapted for collecting blood

If during the operation the flow becomes feeble the donor is asked to clasp and unclasp his hand. If this does not result in an increased flow make sure the manometer is at the correct pressure A slight adjustment may be necessary If the flow is still poor a change in the angle at which the needle enters the vein or a slightly deeper insertion or a withdrawal may be necessary If the flow is still feeble or ceases a second attempt with fresh needle and tubing should be made on the other arm.

A GOOD METHOD OF COLLECTING BLOOD USING THE E.M.S.[1] APPARATUS

The screw cap of the bottle is removed and the bottle fitted with a rubber bung pierced by two 3-in glass tubes One of these tubes acts as an air vent and to the other a length of rubber tubing

[1] E.M.S —Emergency Medical Service. The apparatus is that supplied to the London and Home Counties sectors.

always safer, when possible, to use for purposes of transfusion blood of the same group as that of the recipient

MIXING OF BLOODS

As more than 1 pint of blood should never be drawn from one donor at a time, it is customary to store blood in pint lots Cases sometimes arise in which the infusion of more than 1 pint of blood may be called for In such cases it must be borne in mind that bloods of different groups which may separately be compatible will become incompatible if mixed Bloods of both groups A (II) and O (IV) are theoretically suitable for a recipient of group A (II) Suppose donors or stored blood of both these groups to be available for such a patient, the blood of the group to which he belongs should be given first On no account should bloods of his own group and of the "Universal Donor" be mixed before or during the administration, if this be done the agglutinins of the group O (IV) plasma will act upon the red cells of the blood of the other group, which will enter the circulation of the recipient in a state of agglutination with disastrous results

COLLECTING BLOOD FROM A DONOR

It is not advisable to withdraw more than 1 pint of blood from a donor at a sitting This is also the usual amount given at a single massive transfusion to the recipient In infancy 15 c c of blood per lb body-weight is recommended

The standard solution of sodium citrate supplied is an isotonic concentration (3 8 per cent) Two ounces of this solution is sufficient for 1 pint of blood

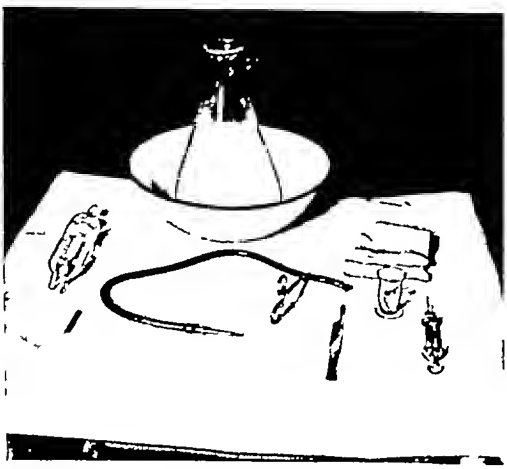


Fig 70
Requisites for collecting blood from a donor

Apparatus—The following simple requisites suffice —

- Sphygmomanometer
- Ether (for sterilizing the skin) and swabs
- Sterile towels
- Barrel of a 10-c c syringe
- Scalpel
- Hypodermic syringe and needle
- Novocain (1 per cent)
- French's needle with rubber tubing attached
- Small hæmostat
- Sodium citrate solution (3 8 per cent)
- Glass flask (1 litre)

} Fig 70

Withdrawing the blood—The donor lies on a table with the bared arm abducted to a right angle and elbow well extended The sphygmomanometer is then applied well above the elbow and the venous circulation obstructed by raising the pressure in the manometer to just below the diastolic blood pressure, this is variable, and it may be worth while to measure the

The apparatus consists essentially of a flask containing the appropriate amount of sodium citrate solution (Fig 74) Within the flask there is a partial vacuum For withdrawing the blood a special perforator is provided and this is connected to a length of rubber tubing To the distal end of the tube a hollow needle which is also provided in the outfit is attached

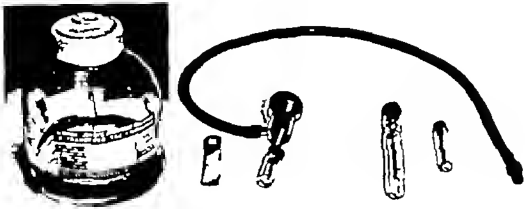


Fig 74

The apparatus. A Transfuso-Vac the special perforator with attached tubing together with hollow needles and a special spanner

Withdrawing the blood—The metal cap of the flask is removed, and the rubber diaphragm with its underlying rubber stopper are pierced by the special perforator in the manner shown (Fig 75) The apparatus is now ready for the reception of the blood The knob controls the rate of suction (Fig 76) and this should not be turned until the needle is within the donor s vein The vein is entered in the usual manner and the knob is turned and blood will flow into the flask The knob is adjusted so that blood flows steadily into the flask In ordinary circumstances a pint of blood is collected in a few minutes (Fig 77)

Administering the blood to the recipient—The perforator is removed from the stopper and the rubber cap is cut away aseptically (Fig 78) The special interceptor is inserted through the perforation in the rubber cork (Fig 79) in the same manner as in the well known Vacoliter for the administration of intravenous saline The flask is now inverted and slung upon a convenient stand To the end of the tubing a vein cannula is attached The recipient s vein is exposed in the usual manner and the cannula inserted

The blood is allowed to gravitate into the vein and the rate can be regulated by the screw clip

DRIP BLOOD AND SALINE TRANSFUSION USING A VACOLITER AND A TRANSFUSO-VAC

By a very simple modification of the apparatus provided by the manufacturers a drip blood and saline transfusion can be administered The Transfuso-Vac full of blood and the Vacoliter full of saline are hung on a and a French's needle is attached (Fig 72) The blood is collected in the same way as described previously

ADMINISTERING BLOOD TO THE RECIPIENT

The simple apparatus used for the administration of a massive saline infusion is quite satisfactory for the transfusion of citrated blood

When it has been ascertained that the saline in the apparatus is gravitating into the vein, the blood is poured into the flask or funnel Finally before the cannula or needle is removed, a few ounces of saline is added to ensure that every drachm of blood is utilized

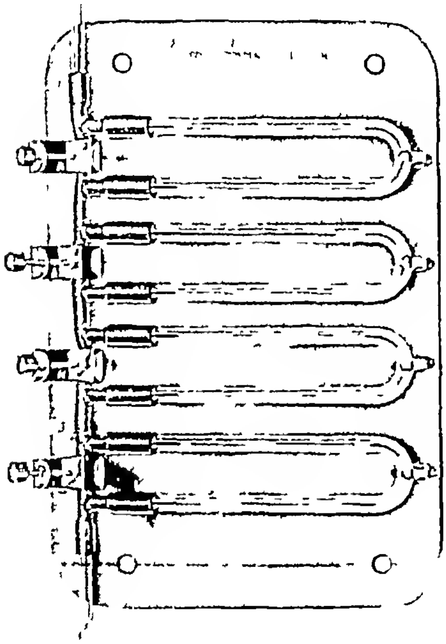


Fig 73

The flow regulator (*Marriott and Kekwick*) (*Bell & Croyden*)

Throughout the transfusion a careful watch is kept for any untoward symptoms This is especially important during the administration of the first few ounces The occurrence of any such symptoms calls for immediate cessation of the transfusion.

Blood must be administered slowly, and with this simple apparatus about twenty minutes, or a little more can be expended in the administration

When more control over the flow is desired, recourse should not be made to any form of interceptor designed to regulate a flow of saline While such interceptors are entirely satisfactory for non-corpuscular fluids, they frequently become blocked in the case of blood

Marriott and Kekwick have designed a flow regulator which overcomes this objection An approximate flow of 40 drops a minute results when one U-tube is used and the reservoir is placed $3\frac{1}{2}$ ft. above the vein if two tubes are used, the rate is halved if four are employed, it is halved again

When the E M S apparatus has been used for collecting the blood is administered in exactly the same way as stored blood (*q v*)

BLOOD TRANSFUSION, USING A TRANSFUSO-VAC

The Transfuso-Vac is a particularly valuable apparatus for performing blood transfusion It possesses certain advantages —

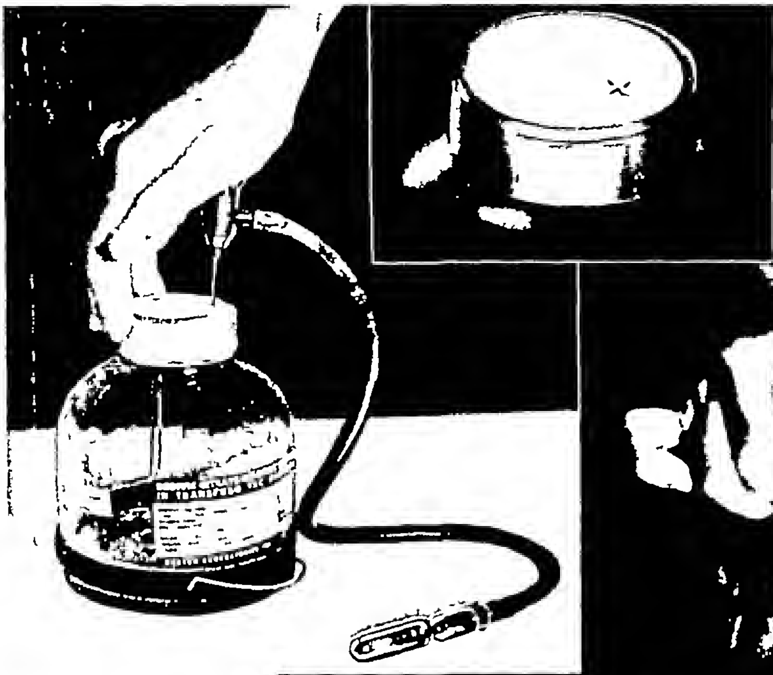
(*a*) The transfusion can be carried out anywhere, even under the most unfavourable conditions

(*b*) As the flask contains the correct amount of citrate solution, time and trouble are saved

(*c*) The blood is withdrawn and administered without being exposed to the outside air, therefore absolute asepsis is assured

FIG. 8
The flask now contains a pint of blood. The perforator having been removed the rubber diaphragm is removed aseptically

FIG 79
Inserting the interceptor through the perforation in the rubber cork.



The X shows the point at which the rubber stopper should be pierced

Fig 75
The metal cap having been removed the rubber stopper is then pierced (see inset) with the special perforator

Fig 76
This knob controls the rate of suction It must not be turned until the needle is in the donor's vein

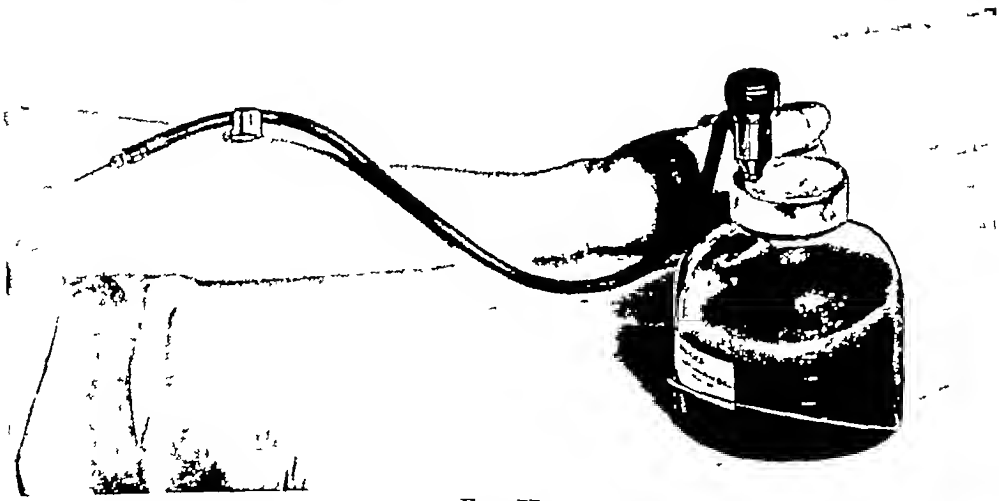


Fig 77
Blood entering the flask A pint is soon collected

required to withdraw the blood. One needle is inserted into the vein and the other pierces the rubber diaphragm. The hæmostat is removed and the blood flows into the bottle by virtue of the vacuum.

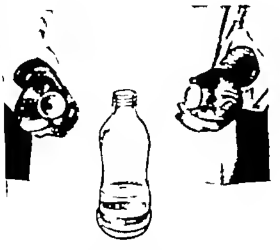


FIG 81

Citrate solution has been placed in the bottle. The rubber diaphragm is about to be inserted into the screw cap.

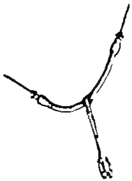


FIG 82

One French's needle is inserted into the vein and the other through the diaphragm of the bottle.

PRESERVED BLOOD TRANSFUSION

The preservation of blood entails the use of a preservative fluid and the maintenance of resultant mixture at a constant temperature of 2° to 4° C. A 3.8 per cent. solution of sodium citrate has proved satisfactory and is in general use. One part is mixed with nine parts of blood.

On storing, blood settles into its constituent layers; the red cells pass to the bottom of the container and are separated from the plasma by a thin layer of leucocytes. The plasma is lemon yellow in colour and cloudiness in it is due to the presence of lipoids which have been ingested by the donor before the blood was withdrawn. It is thus advisable to ask the donor not to have a fatty meal before visiting the transfusion centre.

During the course of the next few days hæmolysis begins among the red cells, and after ten to fourteen days a faint pink layer starts to show in the plasma next to the packed erythrocytes. This is hæmoglobin, which is passing out of the red cell layer and can now be seen. The plasma has meanwhile become more amber in colour, and after about twenty-one days becomes faintly tinged with pink throughout due to the increase in the amount of free hæmoglobin in the container.

Preserved blood is unsuitable for administration if :—

(a) The degree of hæmolysis is such as to produce more than a faint pink tinge in the plasma. (The pink tinge usually appears about the end of the third week.)

(b) If hæmolysis has proceeded very rapidly. This may indicate that the bottle is infected or that it has not been kept at a constant temperature. If a bottle of preserved blood has been removed from the refrigerator and allowed to warm to room temperature it should be used within the next twelve hours as hæmolysis will proceed apace. Similarly, freezing of the blood causes an almost instantaneous hæmolysis and such a bottle should be discarded.

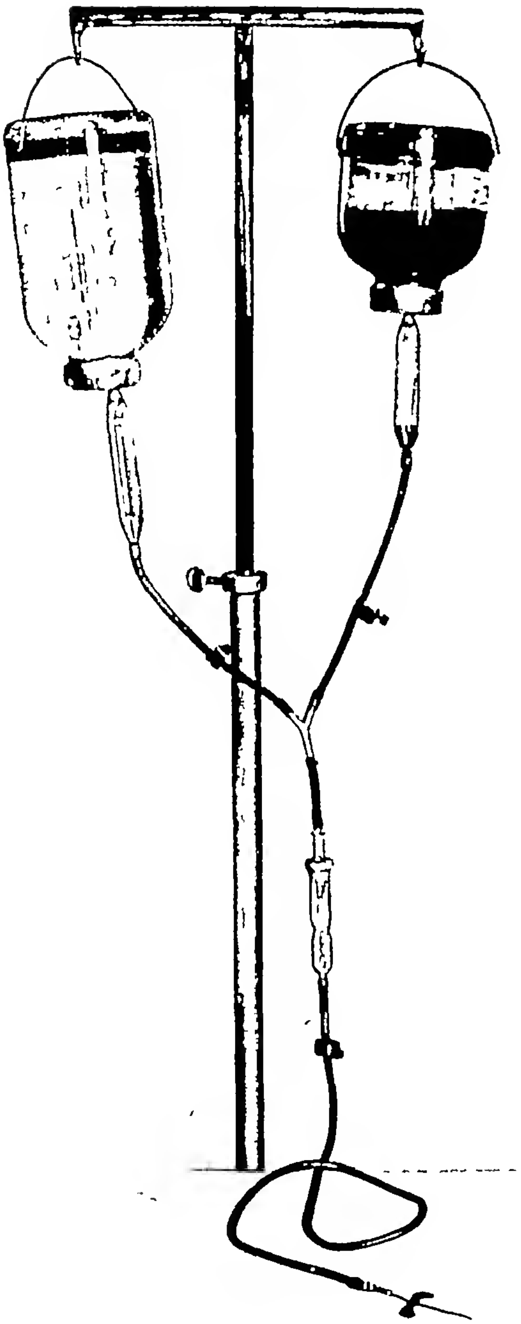


FIG 80

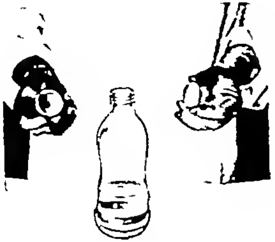
A Vacoliter and a Transfuso-Vac assembled for giving drip blood saline solution

stand (Fig 80) and the rate of flow from each is controlled by a screw adjustment on the tubing A special stand which is clamped on to the head of the bed can be obtained , although not essential, it is a very handy piece of equipment

Drip-blood transfusion and drip-blood transfusion combined with drip-saline infusion has an ever-widening field , in fact, in most conditions the drip method is the ideal way of replenishing the circulation There are a large number of sets of apparatus available for administering blood or blood and saline drop by drop but space does not permit a detailed description of them all The surgeon will employ the apparatus with which he is most familiar, or with which he is supplied

THE TRANSFUSO-VAC PRINCIPLES APPLIED TO THE EMERGENCY MEDICAL SERVICE BOTTLE

The Emergency Medical Service sterile bottle is filled with citrate solution to the 180 c c mark The rubber diaphragm is placed within the perforated aluminium screw cap (Fig 81), which is then screwed on to the neck of the bottle The cap is screwed home tightly and then loosened half a turn The bottle is now placed in an autoclave at 15 lbs pressure for half an hour Immediately after withdrawal from the autoclave the screw cap is tightened As the apparatus cools a vacuum is produced by condensation of steam , that an efficient vacuum is produced is shown by the "sucking-in" of the rubber diaphragm A piece of rubber tubing 6 in long, with a French's needle at each end, and which has been run through with citrate solution and clamped with a hæmostat (Fig 82), is all that is required to withdraw the blood One needle is inserted into the vein and the other pierces the rubber diaphragm The hæmostat is removed and the blood flows into the bottle by virtue of the vacuum



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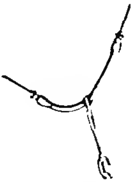

FIG 82

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The addition of dextrose (1 per cent) to the preserving fluid is claimed to delay considerably the onset of hæmolysis

Preserved blood should be shaken as little as possible during storage or transport The best time for transport is during the first two days, before hæmolysis has started, or after the tenth day, when the leucocyte layer has become "organized" into a firm barrier between the packed red cells and the plasma, and little admixture of the blood constituents has taken place

METHODS OF TAKING BLOOD FOR STORAGE

The type of apparatus which appears to be the best yet devised for large-scale transfusion is that of Boland *et al* It is a completely closed unit the bottle is not opened either for filling with blood or for administration, and thus the dangers of infection are practically eliminated Its use is shown in Fig 84

Fig 83
The gas mantle filter for use with the E M S apparatus

Filters—All preserved blood needs to be filtered before being given to the patient owing to the separation during storage of small amounts of fibrin, lipoid material, and the breakdown products of leucocytes and platelets

Two main types of filter are employed in the E M S apparatus —

(*a*) *The glass bead filter* has the advantage of being indestructible

(*b*) *The gas mantle filter* (Fig 83) is extremely efficient, but has to be changed each time the apparatus is used

Temperature of the blood—Before use the blood must be warmed carefully by putting it into a basin of water at 37° C This temperature should be controlled by a thermometer as preserved blood will clot very easily if heated above this temperature Administration of the blood at room temperature will be usually quite satisfactory

ADMINISTERING PRESERVED BLOOD

The delivery unit and air inlet are inserted and the bottle is suspended about 3 ft above the patient (Fig 85) The air is allowed to flow out of the delivery tube, and when it is completely filled with blood the clamp is closed The needle or cannula is then inserted into the recipient's vein The chirping " sound of the air coming up through the blood from the air-inlet needle gives an indication that the flow is proceeding satisfactorily

The administration of the contents of further bottles of blood is effected by taking the outflow needle out of the empty bottle before air has entered the delivery tube and plugging it into a second bottle, followed by the air-inlet needle Saline or glucose saline may be administered at the same time as the blood by using a similar delivery set and pushing the recipient's needle through the lower end of the delivery tube from the bottle of blood Similarly stimulant drugs may be given by injecting them into the delivery tube

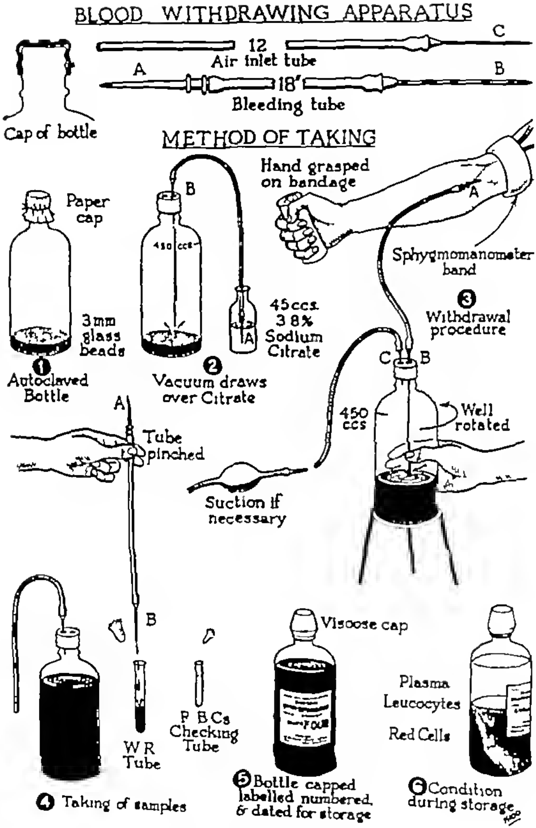

FIG. 84

Method of taking blood for storage

CONCENTRATED RED-CELL SUSPENSIONS IN THE TREATMENT OF ANÆMIA

When the plasma is withdrawn from bottles of stored blood, there is left behind a mass of settled red cells which hitherto have been rejected These red cells are in a concentration of about 8 million per cubic millimetre contained in a very small amount of plasma

In cases of anæmia, with normal blood volume, the administration of such concentrated cells has the great advantage that the blood volume is increased only slightly, and the deficient factor alone is added to the blood stream Thus a severe anæmia will be corrected more quickly than by the administration of whole blood, in which the fluid of the plasma has to be excreted, and the increase of plasma protein may cause such an increase in blood volume, by osmosis, that cardiac failure may supervene

Bottles of concentrated red cells are prepared from stored blood, after the plasma has been withdrawn, by mixing the sedimented cells of the same group These are drawn by a suction pipette from under the "white cell layer," which is left behind in the bottle Usually the red cells of two and a half bottles of stored blood are needed to make 1 pint bottle of concentrated red cells A small test-tube of the cells is attached to the neck for cross agglutination with the recipient, a test which must be carefully done each time The red cells used should not be more than ten days old, as their fragility will be very considerably raised after this time

The fluid is slightly more viscous than stored blood, but is easily administered through the E M S delivery apparatus (see Fig 85) Transfusion should be slow, at the rate of 100 c c per hour

Five hundred cubic centimetres of the concentrated red cells will raise the hæmoglobin value from 12 to 15 per cent , and consequently a case of anæmia with a hæmoglobin value of 30 per cent can be raised from 80 to 90 per cent in about twenty hours without ill effect This is about three times as rapid as the safe speed for a transfusion of normal blood to raise the hæmoglobin to this value

This method has great value when an operation of some urgency is indicated in a case suffering from a severe anæmia Apart from this, the utilization of these cells as a by-product from the plasma bank is of considerable economic value

BLOOD TRANSFUSION REACTIONS

It is important to realize that the transfusion of blood frequently gives rise to mild, and sometimes to severe, and even fatal, reactions According to Pemberton *et al* the mortality from this operation is about 1 17 to 1 46 per 1,000

Experience shows that reactions occurring after transfusions with stored blood are more frequent than when fresh blood is employed C P Stewart found a total reaction incidence of 12 3 per cent in transfusions of stored blood not more than fourteen days old He regards fourteen days as the safe limit of storage In the Home Counties the limit usually set is twenty-one days

Reactions are more readily prevented than cured There are two main types of reaction, the non-hæmolytic and the hæmolytic, the former occuring with much greater frequency

NON-HÆMOLYTIC REACTIONS

This type of reaction, otherwise known as the " common febrile," the " anaphylactic," or " proteolytic " reaction, occurs with varying intensity in some 50 per cent of all blood transfusions (Plummer), though fortunately fatalities are rare It is believed to be due to the introduction of foreign protein in the form of old blood clot, bacterial contamination of the solutions or vessels used, or to incipient clotting of the donor's blood during transference to the recipient This belief is based on the analogy with the symptoms sometimes resulting from intravenous serum therapy and the fact that it is more likely to arise in recipients who have been sensitized by

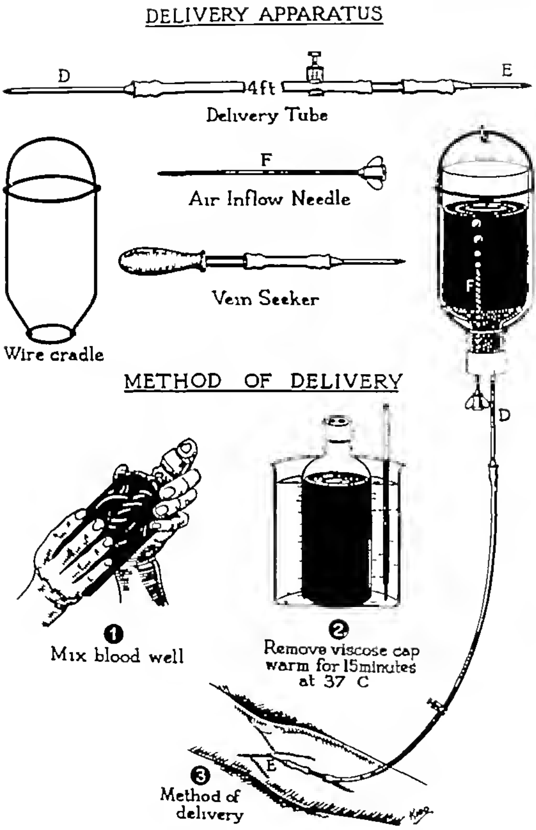

FIG. 83
Method of administering preserved blood.

a previous transfusion from the same donor, and in allergic subjects It was formerly thought that the use of citrate as an anticoagulant was in some way connected with this reaction, but this has now been disproved

In the majority of instances the symptoms of the common febrile reaction consist of a moderate rise of temperature lasting about twenty-four hours Sometimes, however, the temperature rises to 103° or 104° F within the first few hours and may then be accompanied by chills, and even rigors, the pyrexia continuing for some two to four days Associated with the severer grade of pyrexia are such symptoms as headache, nausea, vomiting and general aching of the trunk and limbs Occasionally with hyperpyrexia there is delirium or mania Urticaria has also been described As previously mentioned, this type of reaction occurs more frequently after repeated transfusions, especially from the same donor, in which event it may lead to severe anaphylactic shock and prove fatal

Prevention—From what has been said above concerning the causes of this type of reaction it is clear that much can be done to prevent it Scrupulous care in the cleansing of all apparatus, glass vessels, rubber tubing and needles is, of course, essential Perhaps even more important, because more likely to be overlooked, is the proper sterilization of water used in the preparation of citrate and other solutions Lewisohn and Rosenthal, for example, found that the incidence of "chills" after blood transfusion was reduced from 12 to 1 per cent by using triply distilled water for making the citrate and saline solutions Obviously, too, if more than a very mild pyrexia is caused and it is necessary to repeat the transfusion the same donor should not be used again if possible In known allergic subjects, except in emergency, an attempt should be made to desensitize by preliminary intravenous injections of 0 5, 1, 2 and 5 c c of the donor's blood at five-minute intervals

Treatment—Should anaphylactic symptoms arise, the transfusion must be stopped forthwith The patient is wrapped in hot blankets and, for an adult, 1 to 2 c c of adrenalin hydrochloride is injected intramuscularly Cardiac stimulants are often necessary

HÆMOLYTIC REACTIONS (INCOMPATIBILITY)

Hæmolytic reactions are less common but more dangerous than the non-hæmolytic reactions They are generally, but not always, due to faulty blood grouping Like the non-hæmolytic reactions, they are more likely to arise after a second or further transfusion from the same donor, the recipient presumably becoming sensitized to the donor's blood

There are two varieties of hæmolytic reactions (*a*) immediate, and (*b*) late, both, of course, being usually due to incompatibility of the bloods

(*a*) **The immediate reaction**—In this form it is believed that the breakdown products of hæmolysis (foreign proteins) produce an acute capillary poisoning with consequent shock and circulatory failure Symptoms usually arise soon after the transfusion has begun Frequently after some 90 to 100 c c of blood have been infused the pulse becomes rapid and the subject notices a throbbing in the head There may also be a sensation of tightness in the chest and severe *pain in the lumbar region* The latter is generally the most constant of all the symptoms and inquiry should be made concerning it In addition there may be laboured breathing and cyanosis and the skin may become cold and clammy Urticaria has also been noted Finally the patient becomes unconscious the pulse fails and death occurs

The appearance of any of these symptoms but especially of lumbar pain whilst the transfusion is in progress is an indication for abandoning the operation immediately In the majority of instances recovery will then follow though jaundice and hæmoglobinuria may occur later If the transfusion be continued in spite of symptoms the patient will either die or the late reaction will follow The importance of meticulous care in the grouping of bloods in the prevention of both varieties of hæmolytic reaction is too obvious to need emphasis

(*b*) **The late hæmolytic reaction**—The late or delayed hæmolytic reaction is perhaps the most important of all since it is the most common cause of death following the transfusion of blood It so frequently leads to renal damage and the impairment of renal excretion that it is sometimes known as the renal or uræmic reaction In this form hæmolysis of the donor's cells leads to hæmoglobinæmia and hæmoglobinuria and renal insufficiency with or without jaundice A similar form of renal insufficiency is met with in blackwater fever eclampsia paroxysmal hæmoglobinuria and in poisoning with mushrooms and potassium chlorate The late or uræmic reaction usually occurs in subjects who survive the immediate reaction

In fatal cases two kinds of lesion are found in the kidneys: (1) a mechanical blockage of the lower or distal portions of the renal tubules, which causes a suppression of urine The blockage is due to masses of acid hæmatin and other crystalline and amorphous products resulting from the breaking down of hæmoglobin (2) widespread acute degenerative almost necrotic changes in the cells of the renal tubules, producing a toxic nephritis, or nephrosis due to such necrosis.

Generally though not always the renal reaction follows the immediate hæmolytic reaction Usually the chills vomiting and dyspnœa etc of the latter are followed in a few hours by jaundice and hæmoglobinuria Renal insufficiency is ushered in by increasing oliguria and finally leads to complete anuria Jaundice is generally transient and though unpleasant rarely needs treatment but anuria if prolonged usually causes death from uræmia in from six to twelve days as in unrelieved anuria from other causes In favourable cases the flow of urine may be re-established without treatment though this only occasionally happens if the anuria has persisted for more than two or three days In most cases treatment is called for Preferably of course measures should be adopted for the prevention of the renal reaction, though apart from such obvious precautions as careful grouping properly prepared solutions avoidance of repeated transfusions from the same donor and so forth this is not always practicable Needless to say transfusion of whole blood should not be given except in emergency to subjects whose kidneys are known to be already grossly diseased For such cases plasma transfusions are to be preferred When transfusion of blood is not a matter of immediate necessity oliguria and anuria can often be prevented by rendering the urine alkaline and ensuring a good urinary volume before the transfusion is given Adequate alkalinization a previous transfusion from the same donor, and in allergic subjects It was formerly thought that the use of citrate as an anticoagulant was in some way connected with this reaction, but this has now been disproved

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ANOMALOUS REACTIONS

Such then are the main types of reaction which may follow the trans fusion of blood, and the means of preventing and treating them There remains a further heterogeneous group of cases in which ill-defined reactions occur at times in spite of the most careful precautions The causes of these reactions are obscure though it is not improbable that the quantity of blood used and the rate at which it is given play an important part (Marriott and Kekwick) Experience shows that elderly subjects perhaps with undiagnosed cardiac and renal lesions and with rigid arteriosclerotic blood vessels do not tolerate well the comparatively rapid introduction of large quantities of fluid directly into the circulatory system. Cardiac failure is an ever present danger and if transfusion of blood in large amounts must be given rapidly a careful watch for basal râles dyspnœa and other signs of cardiac distress must be maintained whilst the transfusion is being given. If such signs appear the operation must of course be abandoned at once Elderly patients with chronic anæmia are also liable to comparatively sudden heart failure Caution is also advised in cases of acholuric jaundice (Dawson) and other hæmolytic anæmias Despite published statements to the contrary (Polayes and Lederer) experience teaches that blood transfusion is best avoided in any form of Bright s disease in which renal function is impaired acts (*a*) by promoting diuresis, (*b*) by preventing the precipitation of acid hæmatin in the renal tubules, and (*c*) by protecting the cells of the tubules from acid or other noxious agents excreted by the kidneys Preventive alkalinization is best achieved by giving orally the following mixture —

Potassium citrate	gr xxx
Sodium bicarbonate	gr xxx
Syrup of orange	minims xxx
Water to $1\frac{1}{2}$ oz	

three, four, five or more times in the twenty-four hours over a period of two or three days if possible until the reaction of the early morning (pre-breakfast) specimens of urine are consistently alkaline (pH=7 6 minimum)[1] and the average volume of urine is not less than 50 oz per twenty-four hour period The intake of fluid during this period should not be less than $2\frac{1}{2}$ to 3 pints per diem If possible the transfusion should not be given until these conditions have been fulfilled, and the alkaline mixture in the dose which has been found satisfactory should be continued for a few days after the transfusion has been given No danger of alkalosis is to be feared in subjects whose renal function is normal, however large the dose of alkaline salts used

Treatment—When marked oliguria (under 10 oz of urine per twenty-four hours) or anuria has occurred after transfusion of blood in subjects who have not had preliminary treatment on these lines the following procedure is recommended

Except in the presence of a severe degree of jaundice, anuria of less than forty-eight hours' duration does not call for urgent treatment, but catheters should be passed at six-hourly intervals both day and night to assess progress In subjects whose kidneys were previously healthy, renal function will not generally become seriously or irreparably damaged in the first forty-eight hours, and spontaneous recovery may well take place If there has previously been much loss of fluid from bleeding, vomiting or diarrhœa, intravenous saline or glucose by the drip method may well be given in this stage When, however, anuria has persisted for more than forty-eight hours, or when it is associated with intense jaundice, renal function is likely to be severely impaired, and spontaneous recovery is improbable In such circumstances the introduction of large quantities of fluid of any kind directly into the circulation may be highly dangerous and should only be employed if other methods fail In these cases alkalis should be given if possible by mouth in the form of the mixture described above or, failing this, as a 3 per cent solution of sodium bicarbonate per rectum Since renal function is gravely impaired there is some risk of alkalosis, so that the appearance of any untoward symptoms should be checked by an estimation of the alkali reserve of the blood Absorption is, however, so relatively slow when alkalis are given orally that if some such procedure as that now to be outlined be used the risk of alkalosis is not great and certainly does not contra-indicate this line of treatment even if facilities for estimation of the blood

[1] The minimum degree of alkalinity is attained when the addition of a drop or two of bromthymol blue to a few cubic centimetres of fresh urine produces an immediate deep blue colour without any tinge of green

CHAPTER IX

LOCALIZATION OF FOREIGN BODIES BY X-RAYS

SOME of the methods employed for localization of foreign bodies by X rays are so complicated that their use is not practicable where a large number of cases have to be dealt with rapidly. We propose to give an account of simple methods which may be employed by radiologists and surgeons working under average hospital conditions and with standard equipment. Close co-operation between the surgeon and radiologist will result in a much higher proportion of rapid successful extractions than can be obtained by the surgeon following measurements supplied by a radiologist or himself interpreting radiographs.

Methods not to employ.—No attempt should be made to remove a foreign body even in cases in which it may be felt either by direct palpation or by the insertion of a probe without the assistance of radiographs. These may reveal that the palpable foreign body is only one of several, or that some concomitant bone injury is present and may be dealt with at the time of the operation for extraction of the foreign body. Removal of foreign bodies during fluoroscopic examination is not advocated. Not only is there a danger of injury to the surgeon's hands but important structures may be imperilled during the course of an operation carried out in the unfavourable conditions of a darkened room. Stereoscopy may give a good anatomical picture of the position of a foreign body but may be misleading owing to the great difference in the density of the foreign body and bone, the former tending to dominate the picture.

Two cardinal principles.—1. Radiographs taken in different planes should be obtained by movement of the X-ray tube and not by movement of the patient, the reason being that alterations of pressure on the soft parts may considerably alter the apparent position of the foreign body.

2. Skin markings to be used later should be made with a fine needle or sharp-pointed scalpel. The operator will not then be disappointed by finding that the markings have been removed during the preparation of the skin for operation.

TECHNIQUE

A rapid screen examination is made with the object of obtaining a general idea of the position of the foreign body.

Anteroposterior and lateral radiographs are then taken, the part being kept in the one position, the tube only being moved, and care taken that it is accurately centred over the foreign body. A careful study of these will show whether the relation of the foreign body to bony landmarks is sufficiently

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made to determine the accuracy of localization given by measurements on anteroposterior and lateral radiographs of the distance of the foreign body shadow from the shadow of the surface of the part and from the shadow of a bone. The X ray tube was placed at distances from the film varying from 3 to 6 ft. and was centred over the middle of the part and over each border so that the effect of errors of centring could be assessed. The distribution of the several resulting estimations of the position of the foreign body in relation to its true position is shown for measurements taken from the surface shadow in Fig. 87 and from the bone in Fig. 88. The error in placing the foreign body when the tube was centred over the middle of the part at 3-ft. distance was 0·13 in. in the former and 0·2 in. in the latter case. The case of a foreign body further from the film was also examined and in this particular instance the error in placing using measurements from the bone shadow was 0·15 in. The method therefore gives a satisfactory degree of accuracy.

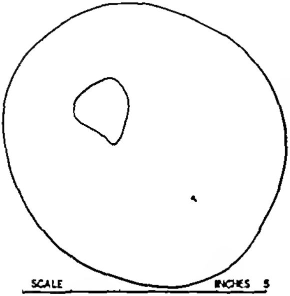


FIG. 87
Foreign body in thigh
Circle = actual position crosses = estimated positions, using measurements from skin surface

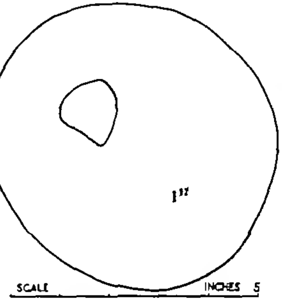


FIG. 88
Foreign body in thigh.
Circle = actual position crosses = estimated position using measurements from bone shadow

The position of the foreign body so determined is marked on a detailed cross-section of the part obtained from a cross-section anatomy. The one available to us is by Eycleshymer and Shoemaker. It is claimed that this enables the surgeon to choose his approach in relation to important structures and gives him information as to the structures he will encounter as he approaches the foreign body.

When the surgeon decides on the basis of this first localization, the position in which the part must be placed at operation this position is adopted on the X ray table and an estimation of the vertical depth below a skin mark is made this acts both as a guide to the surgeon and a check on the first localization as modified by change in position of the part.

For this second localization the method recommended is essentially that described by Shenton. The method is illustrated in Fig. 89. Instead of setting out the measurements graphically however we use a simple formula $d = L\frac{s}{l-s}$ where d = the depth of the foreign body, L = the distance between the films (a constant), s = the smaller shadow shift and l = the larger shadow definite to render further localization unnecessary The surgeon will also decide from the size and position of the foreign body whether an operation for its removal should be undertaken

Fig 86 is a radiograph of a hand of a soldier wounded by a fragment of a bomb In the anteroposterior view the foreign body is localized in

Fig 86

Bomb fragment in wrist Lateral and anteroposterior radiographs

front of the os magnum , in the lateral view it is slightly deeper than the pisiform bone The foreign body was found embedded in the fibres of the flexor sublimis digitorum

When further localization is thought to be necessary we advocate a method based on anteroposterior and lateral views, taken with the precautions previously mentioned, combined with a method of finding the depth below a given point which is independent of tube-film distance and tube-shift

This " given point " is one selected by the surgeon after his preliminary study of the radiographs and through which he proposes to approach the foreign body The position of the patient during the radiographic examination must be identical with the position in which he will be placed on the operating table

The data so obtained are applied to a cross-section of the limb at the appropriate level

Before describing in detail the method recommended we shall discuss the reasons for our choice The use of a standard position of the limb or other part during radiography and maintaining it, whatever views are taken, seem to be precautions for which the necessity is self evident Writers on the subject of localization, however, have cast doubt on the effectiveness of anteroposterior and lateral views in giving the position of a foreign body accurately, especially when the projection of the skin surface in relation to the foreign body shadow is used Experiments were therefore made to determine the accuracy of localization given by measurements on anteroposterior and lateral radiographs of the distance of the foreign body shadow from the shadow of the surface of the part and from the shadow of a bone. The X ray tube was placed at distances from the film varying from 3 to 6 ft. and was centred over the middle of the part and over each border so that the effect of errors of centring could be assessed. The distribution of the several resulting estimations of the position of the foreign body in relation to its true position is shown for measurements taken from the surface shadow in Fig. 87 and from the bone in Fig. 88. The error in placing the foreign body when the tube was centred over the middle of the part at 3-ft. distance was 0·15 in. in the former and 0·2 in. in the latter case. The case of a foreign body farther from the film was also examined and in this particular instance the error in placing using measurements from the bone shadow was 0·15 in. The method therefore gives a satisfactory degree of accuracy.

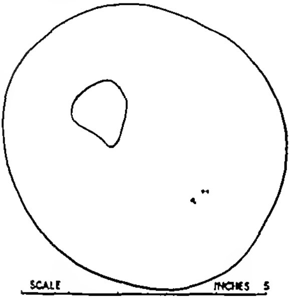
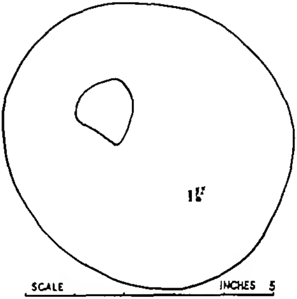


FIG. 87
Foreign body in thigh.
Circle = actual position, crosses = estimated positions, using measurements from skin surface.



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8 Let the surgeon examine the marked cross section and decide the position in which the part is to be placed at operation

Fig 91

Radiographs of shadow shifts.

9 In the screening room place the part in the selected position and mark the spot vertically above the foreign body using a scalpel or needle

10 Open the tube diaphragm to give a long narrow slit in the direction of traverse of the tube

11 Place the box carrying a half plate film on each surface over the foreign body and make two exposures moving the tube two or more inches between them Process the films

12 Measure the foreign body shadow shifts on the two films and apply them to the formula $d=\frac{s}{l-s}$

13 Compare the result with the first localization and pass the information to the surgeon

An example of a foreign body in the calf of the leg with the radiographs taken in both localizations is shown in Figs 90 and 91 and the cross section of the leg with the estimated position of the foreign body in Fig 92 In this instance the fact which proved most useful to the surgeon was that the foreign body was shown to be just below the fascia covering the soleus muscle and it was in fact located there

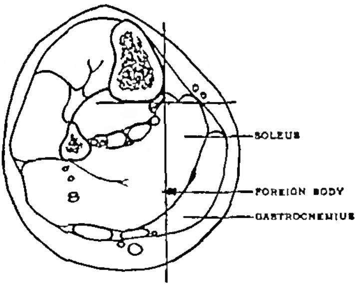

Fig 92

Cross-section of leg with foreign body marked.

The method described is one which we consider simple and accurate It can be applied not only to foreign bodies in the limbs but also with modifications to those embedded in the trunk head or neck

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shift The advantage this method has over other methods which are also independent of tube-film distance and tube-shift is that the shadows of the foreign body are sharp and are measured on films and not the fluorescent screen Half-plate films are quite large enough, and the shadow shift can be measured with dividers on films as soon as they are fixed A slide-rule, which is available in many radiological departments shortens the little calculation

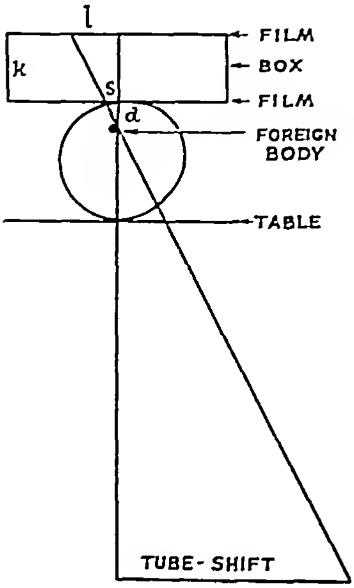

FIG 89
Diagram of method of depth estimation below a marked point

The steps in detail which we take in the localization of a foreign body are these —

1 Screen the part and mark the level of the foreign body by a line of indelible paint round the part

2 Place the part on the X-ray table in the position used in the cross-section anatomy, avoiding any pressure which would deform it and allowing room to slide a casette or envelope under it

3 Centre an X-ray tube 36 in above the mid-point of the part and the line marking the level of the foreign body and another tube similarly at a horizontal distance of 36 in (The second tube will commonly be that of a mobile unit but one tube could be used for both views, provided the part is not moved)

4. Expose one film under the part and then one placed vertically at its side Process the films

5 Measure with callipers (usually available in a radiological department) the anteroposterior and transverse diameters of the part at the level of the

FIG 90
Foreign body in calf Anteroposterior and lateral radiographs

foreign body and the distance of this plane from some landmark, *e g*, the patella in the lower limb

6 Choose the cross-section corresponding to the level of the foreign body (using the last measurement) Trace or otherwise reproduce this, making any necessary adjustment to make it agree with the measured diameters of the part

7. On the wet or dried films measure the distance of the foreign body

shadow (usually its centre) from that of a bone and plot these on the cross section

8 Let the surgeon examine the marked cross section and decide the position in which the part is to be placed at operation

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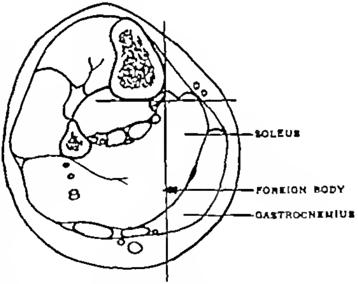

Fig 92

Cross-section of leg with foreign body marked.

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SECTION II

WOUNDS GENERAL OPERATIVE CONSIDERATIONS

CHAPTER X

PRIMARY WOUND EXCISION

(SYN REVISION OF A WOUND "EPLUCHAGE")

PRIMARY excision is the treatment of election for recent wounds but unless the surgeon is quite sure that the wound *is* recent (see definition) he should not even contemplate carrying out this procedure but should follow the instructions given in Chapter XI

Excision of a wound has been likened to clipping flower stems in order to freshen them (Updegraff) it is the *épluchage* of the French surgeons The term revision of a wound is creeping into the literature it means excision as opposed to débridement It is highly desirable to eschew the term débridement when referring to primary wound excision

Definition—A wound is considered to be recent during the time that elapses between its infliction and the development of signs of inflammation This period is usually about twenty four hours

Twenty four hours is an arbitrary period, for the latent interval between contamination and inflammation is influenced by the virulence and extent of the infection, the degree of immobilization of the wounded part, local conditions of moisture and temperature and the power of resistance of the wounded person.

In border line cases the state of the patient's skin and clothing and the appearance of the wound will aid in an estimation of the probable degree of infection

PATHOLOGY

The majority of war wounds are of the *punctured or penetrating type* In such wounds the skin, owing to its elasticity often shows a breach of smaller dimensions than that found in the deeper tissues, particularly the muscles. In addition, the sliding of the tissues which occurs in change of position may further seal off the more extensive deeper damage thus adding the possibility of tension to the other conditions so favourable to wound infection It is fundamental for a surgeon who has to deal with such wounds to have in the forefront of his mind the conviction that injured muscular tissue holds the greatest potential danger The variation in direction of the fibres, the differing extent to which muscles retract after division, and the ease with which damaged muscular tissue becomes invaded by micro-organisms, explain the necessity for this outlook.

All recent wounds of this type must be regarded as infected. It has been found that extension of infection can be prevented provided certain surgical principles are applied without delay

After a clean incision with a knife a protective wall of leucocytes is formed within two hours whereas one to two days may elapse before the same phenomenon is seen after projectile wounds. The effect of diminished blood supply has been demonstrated in animals with infected wounds of both lower limbs; ligature of the main artery induces spreading cellulitis, while infection remains localised in the control limb

Some cellular death occurs even after the use of a sharp knife It is greater after the use of scissors, because there is a crushing as well as a cutting action; and it is at a maximum when the wound is caused by an irregular piece of metal travelling at high speed. The importance of a metallic foreign

In 1897 a German surgeon, P. L. Friedrich, as a result of experimental work, advised treating contused wounds as though they were neoplasms. This apparently was the inception of the treatment of wounds by excision.

body is that it generally carries infection into the tissues, and *it is the extent and virulence of the infection which really matters*

We see, then, that the projectile wound has introduced infection, and has at the same time diminished the powers of local resistance by the injury it has inflicted The wound track is lined by devitalized and necrotic tissue, which forms an excellent culture medium for both aerobic and anaerobic organisms There is likely to be a dead space, containing not only the foreign body but infected material which accompanied it, and blood clot The first reaction of the injured tissues is an outpouring of fluid, which increases tension in the surrounding area and prejudices recovery

PRINCIPLES UPON WHICH WOUND EXCISION IS FOUNDED

After infliction of a wound an interval occurs before clinical evidence of inflammatory reaction becomes apparent Just as tetanus antitoxin, to be really effective, must be given before signs of tetanus appear, so operative treatment of a projectile wound must be instituted before evidence of inflammation arises *The essence of surgical treatment is excision of the tissue lining the track of the wound*, this must be followed by immobilization of the injured part in order to give complete rest

It might be argued that rational surgical treatment for projectile wounds would consist in cleansing the surface wound, the application of a sterilized dressing, adequate splinting, and careful observation so as to provide drainage as soon as signs of inflammation become obvious Experience has shown that such treatment is followed almost invariably by severe infection, and that the surgeon toiling in the rear of inflammation is unable to control the situation

Those who have faith in antiseptics would naturally suggest their application, in the hope of avoiding drastic surgery Antiseptics have been tried and found wanting Sulphanilamide powder, although helpful, falls into this category

The type of operation which is found to be successful in peace time for deep lacerated wounds consists of what is termed "*surgical toilet*" Skin edges are excised and the wound is opened up, foreign bodies, débris and blood clot are removed, this is followed by irrigation with a mild antiseptic, or, more latterly, sulphanilamide powder, and the wound is closed with drainage This succeeds with sufficient frequency to justify its continuance, if infection does supervene, it tends to remain localized

There is a danger that civilian surgeons, when first meeting war wounds, may consider such treatment adequate and may themselves work through the phases of treatment which history records before realizing that a war wound is essentially different and requires a far more elaborate technique The difference, of course, is that more widespread tissue necrosis is present, though it may not be obvious to the inexperienced observer

If the wound is not excised it will become infected, the patient's life will be in jeopardy, and the spread of inflammation cannot be controlled The alternative is to remove the damaged and devitalized tissues, which will be the first to become involved in wound infection Provided signs of inflammation are not actually present, a carefully planned operation to remove not only the metallic foreign body and any other substance carried in with it, but also the injured tissues whose blood supply has been diminished, can be relied on to eliminate all the most serious types of wound infection

The war of 1914 18 saw great changes in the treatment of wounds At first conservative treatment was universal and the results were appalling Tetanus gas gangrene and the hæmolytic streptococcus took their toll without hindrance the mortality of compound fractures of the femur approached 80 per cent It became obvious that something had to be done to the wound in the early stages in addition to attempts at surface steriliza tion and prevention of secondary infection Surface enlargement and drainage improved matters removal of foreign bodies clothing and débris yet more so but still the dreaded complications arose until it became clear that surface necrosis of the whole wound track required removal. When this was adequately done wounds for the first time were under surgical control and the subsequent course could be confidently predicted

What are the disadvantages of this method?

1 THE SACRIFICE OF TISSUE—This sacrifice is more apparent than real the surgeon of experience does not discard any tissue with a good blood supply To an uninitiated surgeon the complete exposure of the interior of a wound may appear an exuberance of zeal an example of overdoing a good thing in fact the literal interpretation of that most unfortunate term surgical interference As time goes on he learns that when properly performed even immense exposures add nothing to permanent functional disability

2 DIFFICULTIES IN PROVIDING SKILLED SURGICAL SERVICES—The surgical staff can be augmented by the rapid training of surgeons of little experience who prove adaptable and keen they should concentrate on dealing with minor wounds in the less dangerous regions A knowledge of gross anatomy is of course essential if this be acquired for one particular region arrangements can be made to select only suitable cases for their attention Anatomical diagrams particularly cross sections of the limbs at various levels can usefully be hung on the wall of the theatre together with printed directions for the surgical treatment of wounds By such arrangements the number of cases operated on in the recent stage will be greatly increased

The provision of increased theatre accommodation need not necessarily entail new construction The majority of war wounds can be satisfactorily dealt with in an ordinary room with improvised fittings and equipment

* * * * * * * *

It must be agreed that the great majority of *early* projectile wounds require early operative treatment If the patient's condition permits the sooner the operation is done the better If signs of shock are so marked that operation is contraindicated methods of resuscitation must be instituted with the object of getting the patient into the operating theatre as soon as possible In this connection it should be borne in mind that adverse conditions inside the wound may be aggravating the shock considerable judgment is required to decide whether a patient is likely to improve beyond a certain degree until operation has removed all toxic factors and procured satisfactory rest to the tissues body is that it generally carries infection into the tissues, and *it is the extent and virulence of the infection which really matters*

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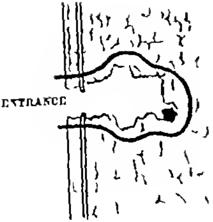
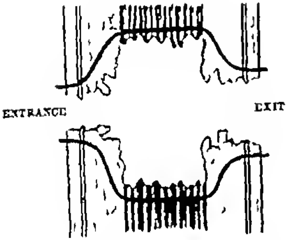
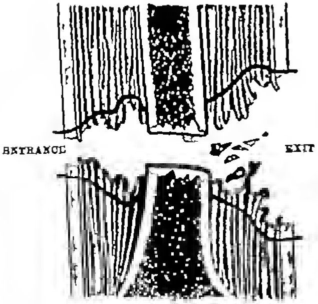


A
Penetrating (syn. lodging) wound.



B
Perforating (syn. traversing) wound.



C
Perforating wound involving bone with a small hole of entry and a larger hole of exit.

Fig 93
The black lines indicate the amount of tissue which should be excised in three typical varieties of wounds

WOUNDS WHICH MAY NOT REQUIRE OPERATION

Bullet wounds with small entrance and exit wounds, may show no swelling of the intervening tissues or other signs of injury to important structures Of all missiles, a bullet travelling evenly at moderate speed is least likely to carry in extraneous matter In campaigns such as the Boer War, where the majority of wounds were due to long-range bullets, the routine practice was non-operative

It must be explained that when conservative treatment is adopted it is just as important to immobilize the part

Multiple superficial wounds due to peppering with tiny fragments of low velocity—"Low velocity" must be noted carefully This type of peppering is almost the prerogative of the hand-grenade, and it must be distinguished from the multiple small external wounds associated with aerial bombs, where the velocity is very high The latter definitely do not fall under this category

WOUNDS REQUIRING OPERATION

The easiest type of wound to treat by excision is the gutter wound, for the whole track is manifestly under vision Unfortunately the problem is usually more complex, and we will proceed to indicate essential procedures in various types of wounds

Penetrating (syn lodging) wounds, in particular, contain foreign bodies, including bits of clothing and blood clot These must be taken away, together with the wall of the wound track (Fig 93, A) Adequate exposure is essential —the surgeon must not shrink from causing hæmorrhage No crevice or other extension of the wound must be overlooked, all hæmatomata must be opened up

Perforating (syn. traversing) wounds—If the perforating wound is of the tunnel (syn seton) variety, *i e*, is approximately the same dimensions throughout its length, and is superficial, ideal tubular excision can be practised More often, however, the deeper parts of the wound are of greater dimensions than those nearer the surface (Fig 93, B), and satisfactory excision of the track becomes correspondingly difficult It must be remembered that absence of foreign bodies does not mean that contamination is absent, and wide excision of the deeper parts is of prime importance Ingenuity must be exercised as to how to get at the depths of the wound with the least possible trauma Ruthless transverse division of intact skin and muscles in order to join exit and entrance wounds is to be deprecated it often leads to prolonged convalescence and serious permanent disability

The wound with a small hole of entry and a large hole of exit, particularly if it is caused by a bullet, sometimes requires only cone-shaped excision of the larger wound On the other hand, if bone has been penetrated, excision of the whole tract, as shown in Fig 93, C, is indicated

ROUTINE WOUND EXCISION AND TEAMWORK

X-ray examination—Preliminary X-ray examination is required when there is a lodging wound Localization of the foreign body should be carried out by an agreed method which is understood by all the surgeons operating

Theatre organization—In the operating theatre the method of lighting is important Diffused daylight is by far the best It is difficult on occasion to bring the wound track perpendicularly beneath a fixed overhead operating

Special instruments—As regards instruments by far the most useful is a pair of large-toothed dissecting forceps with a wide bite and many teeth (Fig 94) the spring should be sufficiently weak to permit compression by the surgeon s hand for long periods with minimum fatigue This instrument is for use during the most tedious and difficult part of the operation viz excision of muscle

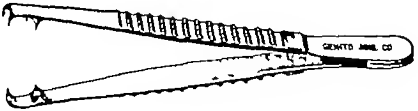


Fig 94

Special dissecting forceps with large teeth These are invaluable for grasping muscle

A sharp scalpel of large size is essential it alone should be used for cutting Scissors though easier to manipulate inflict more tissue damage and spread infection

All instruments should be on the large side The usual hæmostats and scissors are too small for convenient handling when working deeply in muscular tissue

Dry sterilized rubber gloves slightly thicker than standard may be protected by cotton gloves when sharp bony spicules abound they will preserve the gloves from puncture and the surgeon s hands from infection

Technique—There must be free exposure of the deeper parts of the wound not by unnecessary sacrifice of skin but by *longitudinal* extensions Forcible retraction should be avoided and the use of a piece of gauze which is worked backwards and forwards through the wound as a pull through need only be mentioned to be condemned As little damage as possible must be inflicted on the tissues which remain for this reason a sharp knife is essential

Aponeurosis tendon and bone show resistance to invasion by micro organisms and can survive in spite of a greatly restricted blood supply Completely detached fragments of bone are better removed but bone fragments still attached to periosteum can be left particularly if they are essential in providing continuity of bone tissue

The greatest attention must be focused on muscular tissue it is here that the wound often assumes its greatest extent and irregularity Muscular bellies especially if divided completely retract to a considerable distance they must be followed, enlarging the wound as necessary to enable the damaged surface to be removed. A muscle which bleeds on section may be left safely Should it not bleed or contract particularly if it shows the curious brick red appearance seen in early anaerobic infection the extent of the excision must be increased even if it involves sacrifice of all that remains of a muscle or maybe a muscle group The muscle above or below an injury may have been deprived of its blood supply unless it is removed light: one may have to work from the side, or even beneath a limb, in order to avoid moving the patient and imperilling the aseptic field. In black-out conditions movable lights are essential.

It is evident that wounds of the trunk, head and neck carry a high immediate mortality, but even so it is surprising to find that more than two-thirds of hospital admissions for war wounds affect the extremities. Operations upon these cases will be made easier if the limb is held or supported in the same position as when the wound was inflicted; this can often be determined by insertion of a blunt instrument during cleansing of the skin. In the absence of a special orthopædic table apparatus consisting of rope and pulleys can usefully be fixed to the ceiling and walls to suspend the limb in the appropriate position; this will save exhausting work by orderlies and assistants.

The advantages of teamwork are nowhere so apparent as in treating war casualties. During a rush of work special medical officers must concentrate on selecting the cases for operation, arranging for resuscitation treatment when necessary, and timing the work so that the cases shall get to the theatre with as little delay as possible.

Inside the theatre a routine must be established in which all concerned strain to reduce the time taken in dealing effectively with each patient. If two operating tables are available for each surgical team so much the better.

Operations lasting more than one hour impose too much on the resistance of a patient already suffering from shock. When multiple wounds require attention, an estimate must be made of how much the patient can stand; additional surgical help may be obtained, or a decision taken to concentrate on the most serious wound.

THE OPERATION

Caution must be exercised before deciding on a prolonged operation upon a patient from the resuscitation ward. Often his condition seems surprisingly good, but it deteriorates rapidly during operation. If the surgeon be warned at the outset that special treatment has been necessary to improve the general condition, he will not be tempted to do too much. Rapid amputation is often a life-saving measure in such cases.

The use of the tourniquet during operation on the limbs is inadvisable except for amputations and to control rapid loss of blood. The vitality of the tissue is the only sound criterion of the extent of the wound excision; access must be sufficient to enable the surgeon to see clearly whether muscular tissue bleeds on section. If hæmorrhage can be controlled by an ordinary blood-pressure apparatus it will serve the double purpose of indicating the general condition and acting as a tourniquet when necessary.

The skin is cleansed by usual methods over a wide area, having regard to skin markings of foreign bodies and the location of the wounds. A sterilized swab held by forceps over the wound protects it from further contamination. It is important that a limb should be lifted clear of the operating table during this process, and that its entire circumference should receive attention.

as far as its attachment to bone or tendon massive necrosis and infection are inevitable

The neuro-vascular sheaths must be treated with respect The diagrams of cross section anatomy showing the danger areas will be helpful in this respect (Figs 95 and 96)

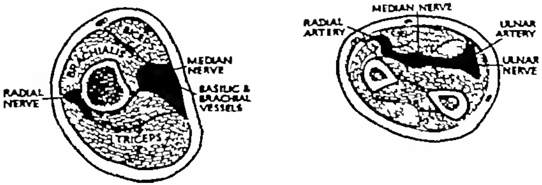


Fig 95

Cross-sections through the upper limb to show danger area in wound excision

If severed nerves are encountered their treatment must depend on the magnitude of the wound and the possibility of securing apposition without undue tension If widely separated it is probably better to leave repair to a future occasion (see chapter on Peripheral Nerve Injuries)

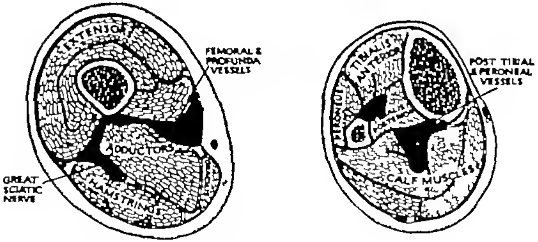


Fig 96

Cross-sections through the lower limb to show danger area in wound excision.

Meticulous hæmostasis is important Individual vessels must be ligatured with fine plain catgut the ligature including as little tissue as possible oozing surfaces may be controlled by a *dry* gauze pack which is left *in situ* for three minutes In addition hydrogen peroxide can be applied When the operation has been completed the whole wound should present a fresh

Directions for Excision of a Wound in the Pre-inflammatory Stage

1. One-quarter inch margin of skin around the wound is ample.
2. Expose deeper parts by longitudinal incisions above and below the skin wound.
3. Avoid unnecessary transverse division of uninjured skin and muscle
4. Remove with a sharp knife the wall of the wound track, including all damaged tissue but avoiding injury to important vessels and nerves
5. Healthy muscle contracts and bleeds on section A brick-red colour may indicate early anaerobic infection.
6. Leave no tabs of muscle, fascia, or fat
7. Avoid, when possible, removing bone fragments still attached to periosteum
8. No guillotine amputation should be performed [1]
9. See what you are doing.
10. Make a record of operative details

Common Errors in Wound Excision

1. Undue sacrifice of skin.
2. Unnecessary transverse section of skin and muscle to join entrance and exit wounds
3. Inadequate exposure of the depths of a wound
4. The use of a "pull-through" of gauze instead of proper exposure and excision of muscle
5. Removal of foreign bodies through separate incision instead of following the wound track

[1] There are certain indications for the guillotine operation notably where there is a relatively large loss of skin The indications, though few, are set out in the chapters on amputations

TREATMENT OF THE WOUND AFTER EXCISION

With the wound excised the surgeon will have completed only half his task. It will be found that subsequent procedure is not so universally agreed upon but its importance must not therefore be minimized. Tissue injured and macroscopically contaminated has been removed but fresh cellular damage has been inflicted by the wound excision and potential infection remains. We have to consider what to do with the wound. Peace time surgery affords no exact parallel for our guidance. Experience of war surgery dictates that there must be no buried sutures and no tension. The explanation is that contamination is still present. Every effort must be made to avoid œdema of the wound.

It is difficult to explain œdema of wounded tissues. Outpouring of serum is generally regarded as a reaction of the defensive mechanism and as a consequence to the uninitiated, œdema might be looked upon almost with favour instead of a phenomenon requiring special preventative measures. As far as our present knowledge goes, œdema appears to be due to the hiatus caused by the injury and increased by wound excision which perforce leads to lack of normal tissue support.

The two great principles which emerge from modern methods of the treatment of the excised wound are *tissue support to prevent or control œdema* and *immobilization sufficient to give complete rest to the injured part*. If these two principles are appreciated the apparent diversity of the methods about to be described will not confuse the surgeon and it becomes possible for him to appraise them at their true value.

Primary suture.—The consensus of opinion is that cases suitable for primary suture are comparatively few. The wound treated thus must be very recent, by which is meant under six hours since infliction. There must be no dead spaces left after thorough excision and the skin must be capable of suture without tension.

Fig 98

Filling a large bomb wound with vaseline gauze after it had been excised. (*Surgeon Lieut.-Commander J. A. Sheppard's case.*)

Packing with vaseline gauze.—Vaseline gauze is innocuous, the tissue support it gives is excellent. Packing with vaseline gauze is undoubtedly the most generally applicable step to follow excision of the wound. Vaseline gauze is packed into the cavity, particularly into all recesses and inter-muscular planes (Fig 98). When the wound has been so filled vaseline is smeared on to the skin around the wound. This is followed by a layer of plain gauze to cover the area.

Immobilization.—No other form of splinting provides such complete rest to the injured tissues as a plaster cast. It should be applied without appearance (Fig 97) and as far as possible it should be shelving from the periphery

The application of sulphanilamide powder—After excision has been completed and satisfactory hæmostasis obtained, sulphanilamide powder should be implanted into the wound The amount should vary between 5 and 15 gm , according to the size of the wound There are various insufflators for this purpose, but none are regularly satisfactory, and the best method is to apply the powder with a dry swab Every nook and cranny should receive its quota After all recesses have been attended to the main cavity is comparatively easily powdered

Fig 97

Primary excision of a shell wound of the thigh completed Fourteen metallic fragments were removed during the course of the dissection The whole wound now presents a healthy appearance (*British Journal of Surgery*)

THE LIMITATIONS OF WOUND EXCISION

Wound excision has, of course, its limitations The principal call for judgment occurs in the case of extensive wounds of the extremities No precise instructions can be given as to when to amputate, but it is obvious that the discovery of injury to important vessels and nerves will turn the scale in favour of primary amputation

In this connection wounds of the *anterior and posterior tibial regions* deserve special mention If the interosseous membrane be traversed there is almost invariably some vascular injury , considerable swelling and increase of tension soon become evident and there is progressive interference with the blood supply of the parts below the injury , signs of incipient gas gangrene are frequently found in the muscles For these reasons amputation will be called for frequently

CHAPTER XI

LOCAL TREATMENT OF INFECTED WAR WOUNDS WITH SPECIAL REFERENCE TO DÉBRIDEMENT

DÉBRIDEMENT is the very antithesis of primary wound excision. Wound excision is a meticulous process, often time-consuming and only to be carried out soon after wounding. Débridement simply implies enlargement of the wound in order to effect free drainage combined with rapid removal of foreign bodies and obviously dead tissue. The latter is the only local treatment permissible when more than eighteen hours have elapsed since the infliction of a wound.

The term "débridement" was introduced by Desault (1744-95), the founder of the *Journal de Chirurgie*, and it was used both by him and Baron Larrey (1766-1842), Napoleon's Surgeon-General, to mean the act of making an incision to enlarge a wound either to facilitate removal of a missile or other foreign body, or to provide drainage.

CONTAMINATION AND INFECTION

War wounds are nearly always deep. As a rule the projectile is jagged. The skin and clothing are dirty; consequently foreign matter is carried deeply into the wound. Given time, dangerous infection is inevitable.

Time is the all important factor. For some hours the surface and depths of a wound may be regarded as outside the body, lying *on* rather than *in* the living tissues; organisms are multiplying, but absorption of toxins is minimal, whilst lymphatic invasion of the surrounding tissues by the organisms has not yet begun. This is the period of *contamination*, and it is during the period of contamination that excision of a wound can be undertaken safely. In general, the period of contamination is twelve hours, though after six hours infection by the hæmolytic streptococcus may have got out of hand.

Certainly after twenty-four hours the period of safety has passed, and the question of treatment must be governed not by general rules but by the clinical appearances and circumstances of the wound.

At the end of the safe period for interference infection succeeds contamination. The multiplying organisms invade the surrounding lymphatics, abundant toxins are produced and absorbed, the patient becomes a sick man. Surgical interference (the term here is used advisedly) now becomes dangerous. Extensive procedures such as wound excision will certainly produce a severe general reaction, while locally they are futile.

This chapter is concerned with the treatment in the period extending from the end of the first twenty-four hours onwards. After a lapse of twenty-four hours the time for primary excision of the wound has passed.

any padding or dressing except on prominent bony points Certain conditions must be fulfilled to ensure the safety of the method —

1 Wound excision must be complete
2 The blood supply of the limb must not be in any doubt
3 The patient's general condition must be good enough to warrant the extra time expended in applying the plaster

If these conditions cannot be fulfilled, an alternative method of immobilizing the part should be employed, at any rate temporarily Extreme caution is needed in dealing with wounds situated in the bend of the knee and in the buttock Cases of compound fracture requiring considerable extension are best immobilized by another method

No windows should be cut As soon as an attempt is made to increase the safety of the plaster case, by the use of padding, windows over the wound, or splitting of the plaster, its efficacy is at once seriously diminished, œdema of the tissues occurs, the support of the case becomes uneven, and the ideals of the treatment are no longer attained These skin-tight plasters are retained in position for from two to six weeks, being changed only when absolutely necessary

In the effort to diminish tissue œdema and preserve the circulation the value of elevation of the injured part must not be overlooked, it is even more important with the closed plaster case than in other methods of treatment

Carrel-Dakin treatment—When, owing to anatomical or other considerations, wound excision has been imperfect, free drainage with wound irrigation, such as the Carrel-Dakin treatment, can be instituted This method fails to provide both tissue support and appropriate immobilization of the injured part, but it has the advantage of encouraging wound drainage and is used when it is known that dead tissue will have to separate

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3 **Pain,** present even when the limb is at rest and accompanied by a feeling of tension is a danger signal pointing to deep infection frequently anaerobic In such a case there should be no hesitation in undertaking an examination of the wound in the operating theatre if necessary under an anæsthetic

4 **Bruising and œdema**—Bruising may become evident many hours after a wound is inflicted Swelling will of course accompany such bruising If the swelling is out of proportion to the amount of bruising it is probable that the extravasated blood is highly infected Increasing œdema with or without bruising accompanied by pain is a clear indication that a dangerous deep infection requiring immediate incision is developing

5 **A thin, foul sanguinous discharge** indicates an anaerobic infection in the depths of the wound and the call for intervention is clear

6 **A spreading mottled bronzing discoloration of the surrounding skin** is the clearest possible indication for laying open the wound removing the involved muscle tissue as far as may be necessary to reach living contractile muscle irrigation with hydrogen peroxide and the freest possible drainage Alternatively amputation may be advisable

7 **The patient's general condition**—A rising pulse rate with pain in and about the wound often presages an advancing gas infection The patient who remains pale and apathetic and does not respond to the customary treatment for shock may show the greyish wound of a severe pyogenic infection which needs drainage or even amputation The other extreme is the patient dying from anaerobic septicæmia who may be excited and talkative although pulseless The temperature does not give an accurate picture of what is happening in the wound Usually some fever is present but a drop to subnormal or a sudden rise to 103 or 104 F is a danger sign

* * * * * * * *

Many patients with war wounds are in fine physical condition at the time of wounding This may be followed by hours or days of exposure pain and hunger and when they reach the surgeon they are depressed by these factors With warmth rest and nourishment they soon rally A few hours sleep may be more essential than surgical attention after rest it is easier to separate those who are ill from infection from those who are relatively unharmed

TYPE OF WOUND IN RELATION TO TREATMENT

Clean through and through wounds of the limb without fracture may generally be left alone if the condition of the patient is satisfactory and there is an absence of local signs pointing to widespread damage along the track An explosive exit causing considerable destruction of the surface tissues which will be septic by this time is better left to granulate

Penetrating wounds, in which clothing and debris may be carried in by a large jagged and slow moving fragment require localization by X rays and their immediate removal Free incision followed by careful examination of the cavity of the wound and drainage should be carried out When the fragment comes to rest in damaged muscle a gas infection is so probable that appropriate steps should be taken by excising the affected muscle tissue and the utmost caution must be exercised in undertaking any active intervention Excessive zeal in dealing with a severely infected wound several days after wounding too often proves disastrous Even attempts to "clean up" or otherwise tamper with an infected wound at the wrong time may turn the scales against the patient There *are* indications for active intervention in late wounds, but, as will be shown, such intervention should be limited to essential measures such as incision for drainage, removal of obvious foreign bodies and dead tissue, and, of course, the control of secondary hæmorrhage

ACTIVE INTERVENTION IN SEPTIC WOUNDS—INDICATIONS AND LIMITATIONS

From the foregoing remarks it will have been realized that after twenty-four hours anything in the nature of stereotyped treatment, viz, routine excision of the wound, is out of place, and the far more difficult problem of selection of cases for active intervention begins Also it will be appreciated that there are wide differences in the practice of individual surgeons of experience Nevertheless, it is clear that the present tendency is to leave a larger proportion of such cases for treatment by dressings (including plaster) and splints than formerly *It should be noted particularly that since the introduction of the closed plaster technique this conservative tendency has been strengthened*

Not only do these late cases demand considerable judgment in the matter of when and when not to operate, they require careful watching If the local or general signs signify that intervention is necessary, it must be purposeful, it must be adequate, but at the same time it must be gentle When the patient is under the anæsthetic the greatest care should be taken in handling the part Vigorous movement may be responsible for releasing toxins and organisms from the wound into the circulation Squeezing, scraping and rubbing are calculated to detach thromboses and to break down nature's barriers of repair It is not exaggeration to state that Volkmann's spoon, when employed in cases such as these, becomes a lethal weapon

Let us consider a case seen on the second or third day after wounding, and review in some detail the factors upon which rational treatment is based

THE LOCAL CONDITION OF THE WOUND AND THE PARTS AROUND

By the second or third day signs of inflammation will usually be evident

1 **Comparative quiescence**—If the wound and the parts around are painless, without bruising, œdema or tenderness along the tract of the missile, and if the skin margins are not reddened or swollen, and there is little or no discharge to be expressed from the depths, the probability is that the wound is quiescent and is better left without active interference

2 **Unusual tenderness,** either localized along the tract of the missile, or over the whole area around the wound, is suspicious of deep infection calling for intervention A radiograph should be taken and examined for a foreign body and gas bubbles

APPLICATIONS TO WOUNDS

In the past the traditional procedure of dressing a wound has played a large part in the attention which surgeons have given to the wounded man It provided an opportunity for estimating progress and gave a natural outlet to his desire to assist the individual It has become more and more obvious that dressing may do harm by the disturbance it causes as well as by the opportunities for reinfection which arise In short it may be stated that a fuller understanding of the local and general defences of the body has been followed by a policy of non interference except for limited and clearly defined objectives during the septic process

Chemical antiseptics—Most chemical antiseptics are harmful to the leucocytes and fixed cells which play such a vital part in the repair of wounds It is more difficult to prove that they are also harmful to the fluid elements poured out on to the wound surfaces but it is probable that such is the case It is yet to be proved that some of the less toxic applications such as eusol Dakin s solution and the various hypertonic solutions are capable of hastening healing we can only say of them that they do not delay healing so much as stronger chemicals

Dressings and trauma—Damage to the granulating surface results from the application and removal of dressings The examination of sections of old granulation tissue will show numerous particles of cotton fibre embedded in the depths and often in the process of assimilation by giant cells—these particles are foreign bodies and act as possible septic foci Furthermore it is commonplace to find bleeding and damage to the surface of the granulations when a dressing is removed In cases where coarse meshed gauze has been left on a wound for some days the granulations have so interwoven themselves with the fabric that great damage is caused when the dressing is removed.

When we wipe a healthy granulating surface we remove wound secretion and "pus"; it is probable that the former has a defensive part to play whilst the latter contains leucocytes, some of which are still living We undoubtedly also disturb the delicate ingrowing margin of epithelium.

Many of these doubts were beginning to arise in surgeons minds at the end of the 1914-18 war At that time the favourite dressings were the Carrel Dakin method, Bipp, and the various flavine preparations. The last had a definite usefulness, for when gauze soaked in 1 : 1 000 flavine was packed into a recently excised wound it definitely delayed healing so that at the end of three or four days it could easily be removed without disturbing the walls of the wound. This was a distinct advantage in transferring cases from the front to the base hospitals. It is interesting in the light of recent developments that the use of Bipp and the Carrel Dakin method, dissimilar as they are, have two things in common. In both cases the wounds can be left untouched for some days, and in each the discharge from the wound can seep away and there is no close intertwining of the granulations into the fabric in contact with the wound. It is possible that these factors, both of which assist drainage are responsible for some of the success of these methods of wound dressing rather than the particular chemical used.

The closed plaster method—The introduction of the closed plaster method of treatment of wounds which at first sight appeared so revolutionary throws further light on the same problem Undoubtedly it has been a notable advance It achieves three things which have hitherto been lacking in all methods of wound treatment —

1 Complete rest for the whole limb
2 Absence of interference with the wound
3 A material in contact with the granulating surface to which the latter does not adhere and which allows pus to seep away

Wounds complicated by fractures of long bones—The dangers of sepsis are enhanced by the widespread damage due to the disruption of the soft parts by the bone fragments Almost without exception, at the stage we are considering, such cases require an anæsthetic with débridement of the wound, at the same time steps may be taken for dealing with the fracture by extension and fixation, either in a closed plaster cast or in a suitable splint *Débridement* involves an examination of the depths of the wound through a free incision, the removal of foreign bodies of all sorts, including detached bone fragments, and the evacuation of blood clot and the ligation of bleeding vessels Damaged muscles abutting on the cavity of the wound must receive most careful scrutiny by the second and third day, in wounds that have received no attention, gas infection with its special predilection to invade muscle tissue may well be present If the muscle in any part of the wall of the wound shows evidence of altered colour or consistence, fails to bleed when it is cut, or does not contract when it is pinched with the forceps, then it must be excised thoroughly *i e*, until living, elastic and contractile muscle is encountered

Damage to the blood-supply of the muscle probably precedes gas infection, thus it will usually happen that the spread will be along anatomical planes and one muscle or group of muscles will usually be affected This fact will be helpful to the surgeon in following up and aborting invasion

Principles to be Observed in Operating upon Wounds Visibly Infected

1 Never attempt primary excision of a wound after 18 hours

2 Operative manipulations must be limited in scope and gentle in execution

3 Incisions may be required for access and for drainage

4. Blood clot, foreign bodies and obviously devitalized tissue must be removed without damage to the living walls of the wound

5 Attend to hæmostasis meticulously

6 Excise damaged muscle until contractile bleeding muscle is reached

7. Provide free drainage, this is imperative

8 Irrigate with a mild antiseptic such as weak hydrogen peroxide (10 vols)

9 Do not use tubes for drainage Pack lightly with vaseline gauze, or use Carrel-Dakin technique

FIG. 99

Private H. A. Admitted 1st June 1940, two days after being wounded. Showing the large exit wound, grossly infected. Treated by the closed plaster technique

FIG. 100

Private H. A. The plaster was renewed on the 14th, 21st and 34th days. Showing the clean granulating wound on removal of the final plaster

Plaster prevents observation of the wound, which has hitherto been so important in estimating clinical progress This is a disadvantage

The most striking feature of this method of treating wounds is seen in the general well-being and comfort of the majority of the patients Although the temperature may be elevated to 100° or 101° for a week or ten days after the application of the plaster, the limb is painless, the pulse remains quiet, the tongue is clean and the patient happy with a good appetite I have used the method for large infected wounds of the soft parts that have received no active surgical treatment (Figs 99 and 100), for compound fractures and for wounds of joints In general the progress of the wound has been as satisfactory as that obtainable by any method The absence of a large number of daily, heavy dressings has lightened the work of the staff In many cases it has been shown that discharge from the wound when the plaster is removed consists of masses of leucocytes, organisms are absent This suggests that the absence of dressings has lessened reinfection of the wound

Technique—The plaster is applied directly to the skin except over prominent points of pressure (*e g*, over the iliac crests) where padding is placed, the wound being filled and covered by vaseline gauze The plaster should be applied so as to immobilize the joints immediately proximal and distal to the wound and to maintain the limb in the functionally effective position In *the upper limb*, when the injury involves the elbow, humerus or the shoulder area, the plaster should enclose the whole arm and shoulder and be carried down the trunk to embrace the iliac crests, but may be lightened by cutting out over the epigastrium

In *the lower limb* I have used the method in wounds of all sorts below the mid-thigh, lack of experience and a wholesome respect for the dangers of wounds in the upper half of the thigh have prevented use of the closed plaster for wounds in this area

If at the time of application of the plaster the patient's temperature is not normal pyrexia is likely to continue for some days, even when the temperature is normal, the disturbance incidental to the procedure often causes a rise to occur during the succeeding days Providing the limb is comfortable, the pulse normal and the patient's general condition good, too much notice need not be taken of a moderate elevation of temperature during the first week or ten days The plaster may be left in place for four or more weeks, but usually will require changing at the end of the first fortnight

Indications for removal of the plaster—1 Discomfort or pain. This may be due to a badly applied plaster or to complications occurring in the wound

2 The plaster cast becoming loose owing to shrinkage of the limb
3 Unsatisfactory general condition of the patient
4 Secondary hæmorrhage
5 Offensive smell

Offensive smell constitutes a disadvantage of the method The patient appears to be less disturbed by it than the bystander As far as possible the patient should be nursed on a balcony Deodorizing bags are proving helpful in minimizing this objection

FIG. 102

Private E. Admitted 2nd June 1940 with this large infected wound of the popliteal space of two days duration. Débridement carried out the same day followed by Carrel Dakin's technique. Three days later a closed plaster was applied.

FIG. 103

Private E. The patient had had an intermittent temperature up to 103° F. but felt and looked well. Showing the condition on removing the plaster on the 17th day.

The Carrel-Dakin technique—This established itself as a reliable method for treatment of septic wounds during the 1914-18 war and may be used with advantage in some cases Lengths of rubber tubing, $\frac{5}{32}$ in diameter, gauge No 7, are led into the depths of the wound (Fig 101) so that fluid instilled through them reaches all parts of the wound frequently The tubes are closed at the termination, whilst a number of lateral holes are punched in the distal inch or two so that the fluid sprays out where required, it must be remembered that the fluid comes out where it is easiest, so that it is best to syringe each tube separately The tubes are arranged so that they irrigate the crevices of the wound They are held in place by lightly

Fig 101

Showing the arrangement of tubes for Carrel-Dakin irrigation Note that a distributor is not employed

packing the wound with vaseline gauze strips Glass connections from a reservoir supplying many tubes are useless, as all the fluid may come through one or two holes on the surface and miss the depths of the wound where it is required Each tube should receive about 1 oz of fluid every two hours, but the whole dressing may be left *in situ* for some days The surrounding skin should be protected from the fluid which runs out by covering it with vaseline gauze

Dakin's fluid, for which eusol is not infrequently substituted, is a chlorine antiseptic which interferes very little with vital processes proceeding in the wound, indeed it is claimed that by assisting in the removal of the sloughs it hastens sterilization of the wound Dakin's fluid rapidly disintegrates in the wound, indeed 80 per cent of its strength has gone within five minutes Oft repeated instillations are therefore essential The method has its greatest usefulness in deep, infected wounds which have been

SECTION III

WOUNDS: SPECIAL INFECTIONS

subjected to débridement Carrel's technique can be used with advantage for a few critical days in badly infected wounds, and if they respond they may then be encased in plaster (Figs 102 and 103) In other cases Carrel's method is continued for ten days or so until the wound is fit for secondary suture The Carrel-Dakin method is unsurpassed for sterilizing the surface of the wound prior to skin grafting or secondary suture

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CHAPTER XII

TETANUS

Cl. TETANI is a spore forming organism (Fig 104) which is commonly present in soil and is a normal inhabitant of the intestinal tract of many domestic animals particularly horses Horse ploughing and the use of horse manure are perhaps partly responsible for the heavy incidence of the disease in agricultural districts Tetanus spores germinate under anaerobic conditions and in this they are helped by the presence of tissue trauma and necrosis It has been shown that spores introduced into the tissues under aseptic conditions do not germinate These facts are important because they show that tetanus is more likely to develop in a deep lacerated infected wound

Fig 104

Cl. Tetani, showing spores.
(Professor G. Barnes.

The degree to which the soil of a battlefield is infected is an important factor in determining the natural incidence of the disease and this partly explains why it was common in northern France and Flanders during the early months of the war of 1914 18 Its incidence was greatly reduced by the introduction of prophylactic antitoxin for all wounded and is likely to be further modified by the use of active immunization in the present war It is now widely recognized that no wound or abrasion is too trivial to be infected by tetanus

Other possible sources of infection which may be met with on active service are intramuscular injections, the grey wool which has been used as padding for plaster-of Paris splints over an open wound or abrasion, felt applied over a pressure sore and infected catgut.

PASSIVE IMMUNIZATION

Passive immunization can be produced by a prophylactic injection of antitoxin given immediately after a wound has been received.

The figures given by Bruce show that during the early months of the Great War the incidence of tetanus was as follows —

August 1914	3·8 per 1 000 wounded.
September	0·0 ,,
October	7·3 ,, ,,
November	2·4 ,, ,,
December	1·4 ,, ,,

Subsequently it remained about 1 per 1 000

This use of antitoxin not only reduced the total incidence of tetanus but prolonged the incubation period increased the number of cases showing

expression Sometimes dysphagia is the earliest symptom Progress of symptoms is slow or rapid according to severity Twenty four hours after the onset a moderately severe case has a characteristic expression the risus sardonicus The muscles of the neck and trunk are in a state of tonic rigidity and the back is slightly arched leaving sufficient space for the flat of the hand to be passed between it and the bed without resistance An attempt by the patient to press the back on to the examining hand often leads to increased arching At this stage there is board like abdominal rigidity The limbs are comparatively relaxed and the reflexes normal or increased But for occasional pain in the neck or back the patient is comfortable but movement or jarring tends to increase the rigidity and bring on cramp like pains The effect of movement manipulation or noise in increasing rigidity and pain becomes more marked as the stage of reflex spasms is approached

In the most severe cases reflex spasms begin twelve to twenty four hours after the onset in moderately severe ones after two or three days and in mild ones after five days At first they are initiated by external stimuli such as touching the patient knocking the bed a loud noise or a bright light but later they occur spontaneously at regular and increasingly short intervals until the height of the disease is reached They begin with a sudden spasm in which the muscles of the jaws and trunk are thrown into intense tonic contraction The jaws are tightly clenched the back arched (opisthotonos) the chest and abdomen fixed and the limbs extended Occasionally the trunk is bent forwards (emprosthotonos) or laterally (pleurosthotonos) In a severe spasm respiratory movements are stopped and if prolonged cyanosis develops Such spasms last from a few seconds to a few minutes they are very exhausting and may cause death from suffocation In the early stages the temperature and pulse rate are not much raised, but as the spasms become severe the pulse becomes rapid With severe spasms there is profuse perspiration and often hyperpyrexia to 106 F or more before death The sphincters are not usually affected but there is occasionally retention of urine Aspiration pneumonia is liable to develop and is a contributory cause of death Death is usually due to respiratory failure either by direct stoppage of respiratory movements in a severe spasm or by involvement of the medullary centres In uncomplicated cases death usually occurs within five days of the onset and survival beyond this is in favour of recovery In those who recover the reflex spasms having reached a maximum wax and wane for a few days and then gradually diminish in intensity They do not usually last for longer than fourteen days. The remaining tonic rigidity then slowly passes off until recovery is complete Sequelæ of tetanus are very uncommon.

CLINICAL TYPES

As a guide to treatment the disease may be divided into five types, but it must be remembered that these merge into each other :—

Type I, in which at the onset there is local tetanus only in the wounded limb, rigidity or twitching and the symptoms of generalized descending tetanus only appear later Such cases are mild, have a long incubation period and usually occur in wounded who have received prophylactic antitoxin.

Type II, in which there is only generalized tonic rigidity but without reflex spasms. This gradually increases and then slowly passes off, the whole process lasting from one to four weeks. Such cases local tetanus and reduced mortality The average incubation period in the inoculated was forty-five days as opposed to eleven days in the uninoculated It was found that a single injection only gave protection for two or three weeks, after which the susceptibility was as great as it was before Patients with infected wounds may therefore become susceptible as their passive immunity wears off and then develop the disease, unless the injection is repeated at intervals to maintain passive immunity

To give passive immunity an injection of at least 3,000 I U [1] should be given as soon as possible after the wound has been inflicted The sooner it is given the more complete the protection In very serious infected wounds this should be repeated on the third day and again at weekly intervals for at least four weeks In such cases it may also be wise to double the dose, particularly if the progress of the wound is not satisfactory Repetition is necessary, because the passive immunity given by each injection only lasts two or three weeks

A further injection of 3,000 I U should always be given a few hours before operations or manipulations of an old wound, because these have been known to stir up latent infection and produce an attack

ACTIVE IMMUNITY

In 1926 Ramon and Zoeller showed that active immunization against tetanus could be produced by injections of formolized toxin called toxoid, and a modification of their method is now used in the British Army for soldiers before they go on active service To produce immunity at least two injections are necessary, and in the British Army two injections of 1 c c are given at an interval of six weeks Immunity so produced appears to last for some years and may be permanent

There is, however, considerable variation in reaction in different individuals, and a few give only a poor response A few anaphylactic reactions have been reported after these injections, which have been attributed to the small amount of peptone present in the solution These, however, have not been severe

The advantage of active over passive immunization is that the former can be completed before the soldier goes on active service, so that he is immune to tetanus if he is wounded If further work confirms the complete reliability of this method it will be possible to dispense with prophylactic antitoxin after the wound has been received Up to the present, however, active immunization has not yet been tested on a large scale, and in the stress of war it is not always clear whether both injections of toxoid have previously been given to a wounded man At present a prophylactic injection of antitoxin is also given to wounded regardless of whether they have previously had toxoid

It has been shown that the antigenic effects of toxoid are enhanced if it is given in combination with a vaccine To make use of this fact, injections of toxoid and T A B can with advantage be given together at an interval of six weeks

CLINICAL FEATURES

Trismus is the most common early symptom, and this is usually combined with pain and stiffness in the neck, back and abdomen, and an anxious

[1] International units used throughout

TREATMENT

Treatment should be begun as soon as possible and will be considered under four headings:—

1. Antitoxin treatment
2. Treatment of the wound
3. Control of reflex spasms
4. Feeding and general treatment

Antitoxin treatment.—Further absorption of toxin can be prevented in two ways: by giving antitoxin and by treating the wound.

Toxin is formed locally in the wound and reaches the motor cells of the central nervous system. Meyer and Ransom brought forward evidence to show that toxin passes up the axis cylinders of the motor nerves, but more recent work by Abel suggests that it is carried by the blood and lymph. The evidence is not yet conclusive.

It is certain that the first symptoms appear when a certain amount of toxin has reached the nervous system, and that in most cases at this stage more toxin is still being absorbed from the wound. In most patients, particularly in war when antitoxin is likely to have been given, symptoms appear before a lethal dose has reached the nervous system, and patients who recover show that the amount already there can be neutralized completely. If further absorption and circulation of toxin from the wound can be prevented before a lethal dose has been absorbed, recovery is simply a matter of time.

The aim of antitoxin treatment is to flood the circulation with antitoxin as soon as possible after the first symptoms have appeared. This will neutralize any toxin in the blood and lymph and also prevent further absorption by neutralization at and around the wound. It is now generally agreed that this can be done most effectively by a large intravenous dose of antitoxin. Two hundred thousand I.U. should be given intravenously as soon as possible and before anything further is done to the wound. In giving this dose of antitoxin inquiry should first be made as to previous serum therapy and for any history suggesting a tendency to allergy or anaphylaxis. In cases of doubt, desensitization should be carried out by the usual method. This amount of serum can be given slowly in one dose and need not be diluted or warmed. A solution of 1 : 1 000 adrenalin for hypodermic injection should be at hand and ♏v should be given subcutaneously if symptoms appear. These, however, are unusual. If the whole of the 200 000 units are not available as large a dose as possible should be given at once and the remainder as soon as possible afterwards. If for any reason it cannot be given intravenously it should be given intramuscularly.

It is the practice of many to give repeated doses of serum daily until the disease has almost subsided. This would only seem to be necessary if antitoxin disappeared rapidly from the circulation after injection. Dean's evidence on this point suggests that it continues to circulate for a considerable period.

Spooner investigated the fate of injected antitoxin in four patients, each of whom had been given a single initial dose of 200,000 units. The results of this investigation showed that seven days after injection there are over 10 units of antitoxin per cubic centimetre—that is, a total of 50,000 units—still left in the circulating blood, and at the end of fourteen days 3 units per cubic centimetre—that is, 15,000 units.

Since a prophylactic dose of 3 000 units is usually sufficient to prevent tetanus developing even from a severe wound, the possibility of gaining any advantage from a further injection of antitoxin before the seventh day appears to be doubtful. In severe war wounds it is perhaps wise to give a further are also mild, the incubation period is more than fourteen days, the wound is either very slight or cannot be found, or prophylactic antitoxin has been given

Type III is like type II, but the stage of tonic rigidity passes into the stage of reflex spasms as described above If the reflex spasms are occurring regularly within forty eight hours of the onset of trismus the prognosis is bad, but the longer their onset is delayed after forty eight hours the better is the chance of recovery

Type IV—Splanchnic tetanus is that in which the muscles of deglutition and respiration are involved early and generalized symptoms are slight or do not appear The symptoms are intense dysphagia with crises of dyspnœa This form is very rare it usually follows a visceral infection and is always fatal

Type V—Cephalic tetanus (Kopf) is a form in which irritation or paralysis of cranial nerves appears early and typical symptoms of descending tetanus only later The seventh cranial nerve is the most frequently involved This form follows wounds of the head, face and neck, and the symptoms which may be regarded as a form of local tetanus, often appear first on the injured side The prognosis is good if treatment can be given at once and the wound is not very severe

DIFFERENTIAL DIAGNOSIS

The onset in a wounded man of painless stiffness of the jaw with inability to open the mouth to the fullest extent should always give rise to the suspicion of tetanus, and this is confirmed by the presence of cramp-like pains in the neck and back, stiffness and arching of the spine and rigidity of the abdomen Increase of pain, rigidity or trismus on manipulation of the limbs or body is also suggestive

From the early occurrence of trismus and dysphagia tetanus may be mistaken for local affections of the mouth, throat or temporo-mandibular joint Thus an impacted wisdom tooth, peritonsillar abscess, parotitis and diphtheria have all given rise to difficulty It is important to remember that in these conditions pain is usually a marked feature, while in tetanus it is slight or absent in the early stages Careful clinical examination is usually enough to exclude any of the above

Severe serum sickness, with œdema of the throat and inability to open the mouth following antistreptococcal serum injections for an infected wound has given rise to difficulty

Local tetanus may be mistaken for neuritis or arthritis, but in the former stiffness with relative absence of pain and the presence of a wound in or near the affected limb should suggest the true diagnosis, which is confirmed by the first appearance of trismus

Cephalic tetanus with cranial nerve lesions may be mistaken for meningitis, encephalitis or polioencephalitis The association of a head wound and slight trismus is in favour of tetanus

Basal meningitis, particularly tuberculous, may also simulate generalized tetanus very closely, and in such doubtful cases the cerebrospinal fluid should be examined Cases in which the sight of water, or attempts to drink bring on severe spasms bear a superficial resemblance to hydrophobia, but in such the history is usually enough to make the diagnosis clear If the abdominal rigidity precedes other symptoms tetanus may be mistaken for an acute abdominal condition Leavitt describes a case in which an operation for supposed acute appendicitis was performed Hysterical or epileptic convulsions in a wounded man occasionally give rise to difficulty and the convulsions of strychnine poisoning resemble those of tetanus, but trismus is not such a marked feature In these convulsive conditions, also the history is usually enough to make the diagnosis clear

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The aim of antitoxin treatment is to flood the circulation with antitoxin as soon as possible after the first symptoms have appeared This will neutralize any toxin in the blood and lymph and also prevent further absorption by neutralization at and around the wound It is now generally agreed that this can be done most effectively by a large intravenous dose of antitoxin Two hundred thousand I U should be given intravenously as soon as possible and before anything further is done to the wound In giving this dose of antitoxin inquiry should first be made as to previous serum therapy and for any history suggesting a tendency to allergy or anaphylaxis. In cases of doubt desensitization should be carried out by the usual method This amount of serum can be given slowly in one dose and need not be diluted or warmed A solution of 1 1 000 adrenalin for hypodermic injection should be at hand and ♏v should be given subcutaneously if symptoms appear These however are unusual If the whole of the 200 000 units are not available as large a dose as possible should be given at once and the remainder as soon as possible afterwards If for any reason it cannot be given intravenously it should be given intramuscularly

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Since a prophylactic dose of 3 000 units is usually sufficient to prevent tetanus developing even from a severe wound the possibility of gaining any advantage from a further injection of antitoxin before the seventh day appears to be doubtful In severe war wounds it is perhaps wise to give a further

50,000 units intravenously seven days after the first injection of 200,000 units and to repeat this at intervals of seven days if recovery is not taking place With slight wounds this is probably unnecessary *To continue to give very large doses of antitoxin day after day when the condition is improving or when only tonic rigidity remains is worrying to the patient and a great waste of money and serum*

Antitoxin is also given by the intrathecal and cisternal routes in the hope of neutralizing toxin which has already reached the central nervous system Ransom states that it is then inaccessible to antitoxin, and although this is still disputed by some the balance of the evidence is in favour of this view Weed has shown that the cerebrospinal fluid comes mainly from the choroid plexus, a small amount also passing out along the perivascular spaces to the subarachnoid space From there it travels through the arachnoid villi into the venous sinuses Fluid introduced into the theca will therefore tend to pass into the veins by this route and will not come at once into close contact with the nervous tissue until taken there by the blood This suggests that the intrathecal route is inferior to the intravenous

All parts of the brain and spinal cord are richly supplied with blood vessels and capillaries in close contact with the nerve cells themselves, and antitoxin would reach these more quickly when introduced directly into a vein than if it were first injected into the spinal theca and then absorbed into the venous sinuses On this point the results of animal experiments (Sherrington, Florey) are not convincingly in favour of the intrathecal route

Clinicians tend more and more to favour the intravenous route From a practical point of view lumbar puncture is highly undesirable in tetanus, as it tends to irritate the nervous system and increase the liability to reflex spasms The injection of serum into the subarachnoid space is liable to cause a mild serous meningitis sometimes within a few days, and if this happens before the symptoms of tetanus have subsided a serious exacerbation may result These objections also apply to the cisternal route

It cannot be emphasized too strongly that there should be no unnecessary delay in making the diagnosis or in giving serum

Treatment of the wound—When the first symptoms appear it is probable that toxin is still being formed in the wound and absorbed It is important that this should be prevented as soon as possible by thorough local treatment Disturbance of a wound is liable to cause further absorption, and it should therefore not be touched until antitoxin has been given and had time to circulate so that it is present in the blood and tissue fluids to neutralize any further toxin as it is absorbed Exacerbations of the disease have been known to follow operations on wounds, and it has been known to develop after operations for the removal of foreign bodies from old war wounds Because of this danger no wound should be touched for at least an hour after antitoxin has been given After this period thorough local treatment is very important This should aim at converting an anaerobic into an aerobic wound by thorough drainage, evacuation of pus and removal of foreign bodies, and necrotic or infected tissue Wounds should be irrigated four-hourly with hydrogen peroxide through Carrel's tubes, if for other reasons this is suitable, and dressings should not interfere with free drainage The practice of early excision of wounds which was introduced in 1917 is thought to have been a factor in lowering still further the incidence of tetanus

Control of reflex spasms—Under active service conditions the nursing and management of tetanus present special difficulties The aim should be to keep patients as quiet as possible in a dim light and screened from others The bedclothes should be cradled and all necessary manipulations done as quietly and gently as possible when the patient is most deeply under the influence of sedatives In severe cases it is desirable for a sister or orderly to be near all the time

In mild cases which begin with local tetanus or in which there is only tonic rigidity without reflex spasms and trismus is not severe enough to prevent food being given mild sedatives are all that are needed Potassium bromide in doses up to 20 gr two hourly or sodium luminal up to 1 gr four hourly are usually sufficient to promote rest and sleep The reflex spasms are the dangerous symptom for it is these which kill by respiratory spasm and rapidly cause exhaustion When as is usually the case they are combined with severe trismus they make feeding difficult or impossible The rapidity with which they come on after the first appearance of trismus is a good indication of how severe they are likely to become and of the prognosis If reflex spasms are occurring regularly within forty-eight hours of the first onset of trismus they are likely to be very severe and death will probably occur within six days whatever treatment is given If they are delayed more than forty-eight hours there is a good chance of recovery and the longer they are delayed the less severe and prolonged they are likely to be Early onset is an indication that they will be difficult to control and that the most drastic measures will have to be used The length of the incubation period is a less certain index of severity partly because it cannot always be accurately measured Infection of a wound or germination of spores may not occur for some days after it has been received and thus the incubation period may be much shorter than is apparent and the disease more severe than is expected Generally speaking an incubation period of less than seven days means a very severe attack seven to fourteen a moderately severe one with a good chance of recovery and over fourteen a mild one Cases with a very long incubation period are seen more frequently in war when prophylactic antitoxin has been given

To control reflex spasms avertin or paraldehyde given rectally as for basal anæsthesia are the drugs of choice If they appear early increase rapidly in frequency or are severe or prolonged one of these should be used at once Avertin the use of which in tetanus was first suggested by Momburg and Rotthaus is the most effective It should be given rectally in doses of from 0·07 to 0 1 c c per kilo of body weight (estimated) and it usually stops reflex spasms and relaxes the jaw for a period of from four to six hours As soon as the spasms begin to return a further dose should be given the exact amount being judged by the effect of the previous one and the severity of the spasms Severe spasms affecting the respiratory muscles and threatening suffocation are an indication for a larger dose Doses usually have to be given two or three times in the twenty four hours and should be continued according to the severity of the spasms As these grow less their frequency should be reduced Two or three basal anæsthetic doses of avertin have been given daily for seven days to adults with severe tetanus and recovery has occurred without any ill-effects Occasionally repeated injections cause slight rectal irritation, but they are usually well tolerated

Paraldehyde in doses of from ½ to 1 drachm per stone of body-weight dissolved in warm normal saline (ʒi to ℥iss saline) and given per rectum, is almost as effective as avertin and may be easier to use on active service With both avertin and paraldehyde there is a tendency to cyanosis, and for this warmed nasal oxygen should be given continuously by nasal catheter If there is moisture in the lungs atropine should be given subcutaneously in doses of $\frac{1}{100}$ to $\frac{1}{50}$ gr

Other drugs which are useful at times for the control of reflex spasms are nitrous oxide and oxygen, chloroform or ether by inhalation, evipan intravenously as for basal anaesthesia, nembutal gr iss (1½) by the mouth four-hourly or more frequently if necessary, morphia and heroin Nitrous oxide and oxygen, chloroform or ether may be useful to control spasms quickly when they first come on while the other safer remedies are being prepared The two latter should not, however, be used more than is absolutely necessary and are useless in cases of severe respiratory spasm when respiration has been stopped When this happens evipan is valuable to control spasms temporarily Its action however, is not sufficiently prolonged to make it suitable for continuous use Nembutal is useful if the spasms are not very severe and it can be given by the mouth Morphia and heroin combined with atropine are sometimes useful for the relief of pain, but they should be used sparingly on account of their depressing effect on the respiratory centre

In using any of the above the dangers of heavy dosage have to be weighed against the severity of the disease Aspiration pneumonia is one of the most dangerous complications of tetanus, but in severe cases the risk of predisposing to this is less than that of allowing spasms to continue unchecked

In the present war, during the retreat and evacuation of the B E F from France the question of movement and evacuation of cases of tetanus arose The decision on this point may be a difficult one and depends on the severity and stage of the disease at which a decision has to be made as well as on the severity of the wound which has caused the infection Patients with reflex spasms who have developed them within four days of the onset and can be left in comparative quiet should not be moved as they will almost certainly die Patients who have not developed reflex spasms within four days of the onset or in whom reflex spasms have almost or completely ceased, leaving only tonic rigidity, can usually be moved with safety

Feeding and general treatment—An attack of tetanus involves prolonged exertion with little rest or relaxation, and this is combined with toxæmia severe pain and often a high temperature To pass successfully through such an ordeal, food and fluid are of vital importance In patients who survive reflex spasms may continue from seven to twenty-one days, and in the later stages especially exhaustion and dehydration may be severe Unless, however, there is intercurrent disease, such as a severe infected wound or pneumonia patients rarely die of exhaustion

In every patient an attempt should be made to give 1,000 calories daily in fluid form and at least 3 pints of fluid One of the most important duties of the sister in charge is to see that nourishing fluids are given whenever possible Sugar and water or lemonade milk milk and water Benger s and egg beaten up in milk are all satisfactory Broth or Bovril containing salt may also be given to make up for loss of chlorides from excessive sweating Usually tetanus patients are thirsty and take fluids well If trismus or reflex spasms are severe removal of teeth may be necessary before feeding is possible A stomach tube can then be passed under basal anæsthesia and fluid given through this Avertin is particularly valuable in these difficult cases for it relaxes the jaw and inhibits the reflex spasms which would otherwise be provoked by any attempt to feed When feeding is difficult the attempt should be made when the patient is most deeply under basal anæsthesia because the liability to excite trismus and reflex spasms is then least Avertin is also valuable in the rarer cases in which the muscles of deglutition are affected and in these again a stomach tube may be useful When feeding is impossible by the mouth normal saline with glucose should be given by rectal drip

PROGNOSIS

The severity of an attack of tetanus in war depends mainly on the site type and severity of the wound and whether a prophylactic dose of antitoxin has been given The effects of previous active immunization or of a single dose only of toxoid in modifying an attack cannot yet be estimated When prophylactic treatment has not been given there tends to be a direct relation ship between the severity and degree of infection of the wound and that of the disease Other things being equal wounds of the head and neck and upper extremity cause more severe attacks than those of the lower Prognosis is also dependent on the age and physique and whether there is any intercurrent disease It becomes worse over forty and is very bad over sixty If there is intercurrent toxæmia shock hæmorrhage or exhaustion from wounds or infection even a mild attack may be fatal

In assessing prognosis in addition to the above considerations the length of the incubation period and the rate of onset of symptoms are of great value (see tables Figs 10 , 106 and 107) The former is only a rough guide because it cannot be measured accurately If it is less than seven days the prognosis is usually bad if it is more than fourteen the prognosis is usually good. The true incubation period however is often a good deal shorter than is apparent because the infection of a wound or germination of spores only occurs some time after it is inflicted The period of onset of reflex spasms which is the time between the onset of trismus and the occurrence of regular reflex spasms is the most useful guide to prognosis If these come on within forty-eight hours of the onset of trismus the prognosis is bad If they do not appear until after forty-eight hours there is a good chance of recovery and the longer they are delayed the better this chance becomes This may be expressed in another way by saying that a lethal dose of toxin tends to produce reflex convulsions within forty-eight hours of the first symptom Prognosis is also better if treatment and particularly a large dose of antitoxin can be given early in the attack.

To be able to estimate the severity of a case in the early stages is a great help in treatment particularly in judging what measures should be used to control the reflex spasms

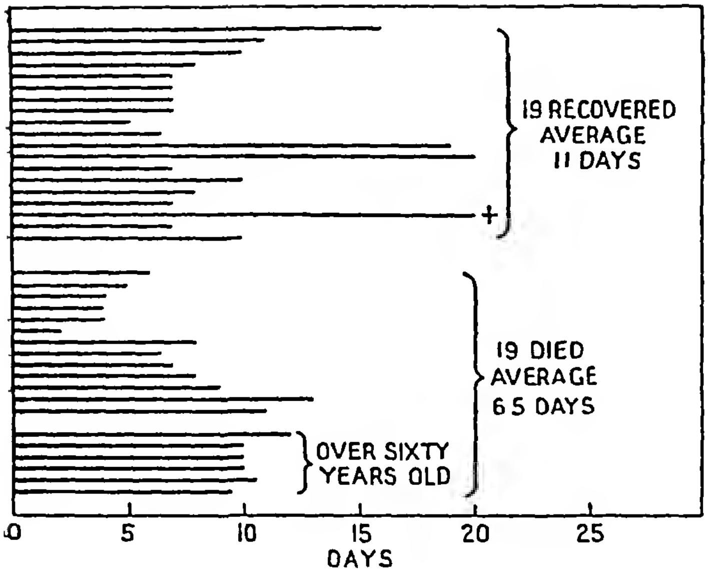

FIG 105

Chart showing duration of incubation period in fatal and non fatal cases of tetanus

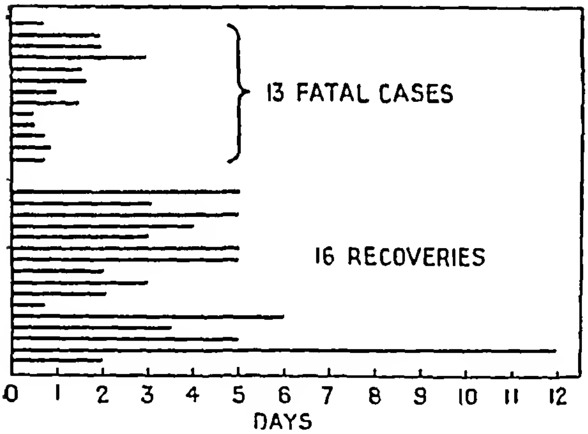

FIG 106

Chart showing duration of period of onset in fatal and non-fatal cases of tetanus (under sixty years)

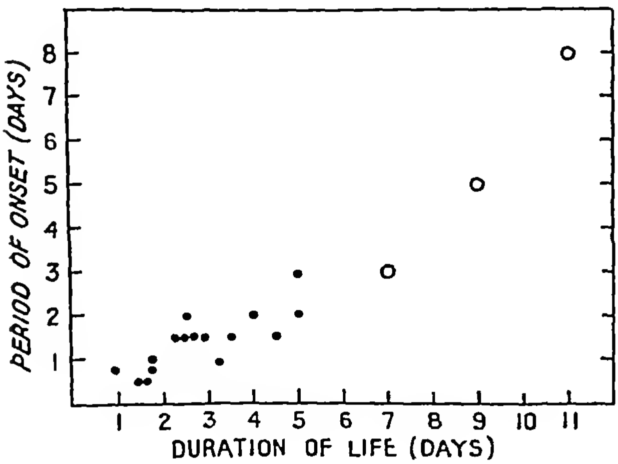

FIG 107

Chart showing relationship of period of onset to duration of life in 19 fatal cases of tetanus The open circle denotes presence of either old age or pneumonia

Figs 105, 106, 107 by kind permission of the "Lancet"

SUMMARY OF TREATMENT

The treatment of tetanus in war may be summarized as follows —

1 As soon as possible after the diagnosis is made give 200 000 I U of antitoxin intravenously If this full amount is not available give the largest dose possible and the balance as soon as possible If it cannot be given intravenously give it intramuscularly In patients with severe infected wounds give a further 50 000 units intravenously every seven days until the reflex spasms are subsiding Give the same dose before any subsequent operation on the wound

2 Do not perform lumbar puncture except for diagnostic purposes and do not give antitoxin intrathecally

3 One hour after antitoxin has been given treat the wound After appropriate surgical treatment irrigate with hydrogen peroxide

4 Keep the patient as quiet as possible in a dim light If reflex spasms have not begun give large doses of bromide and frequent nourishing fluids

5 If reflex spasms do not come on for four days or longer after the first symptom and are not severe treatment with avertin or paraldehyde need not be started but one of these should be held in readiness to be used if they become severe

6 If reflex spasms come on within four days of the first symptom treatment with avertin or paraldehyde should be begun at once and continued according to the severity and duration of the spasms When prolonged spasms cause respiratory embarrassment dosage should be larger and more frequent

7 With basal anæsthesia warmed nasal oxygen should be given as required to prevent cyanosis and atropine hypodermically if the lungs are moist

8 Necessary manipulations such as the giving of enemas hypodermic injections or wound dressings should be done when the patient is most deeply under the influence of sedatives

9 During recovery reduce sedatives gradually according to the progress of the reflex spasms

10 Treat hyperpyrexia by tepid sponging

11 Do not move the patient during the phase of reflex spasms if this can possibly be avoided

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CHAPTER XIII

GAS GANGRENE

GAS gangrene (Fig 108) results from infection by anaerobic, gas producing organisms of lacerated tissues especially muscle On the other hand it must be realized that many war wounds become infected with gas-producing organisms and still more can be proved bacteriologically to contain anaerobes, without clinical evidence of gas gangrene in the wounded tissues

Etiology—In order of frequency the micro-organisms usually responsible are Cl welchii Cl septique and Cl œdematiens Usually several species are present in the same wound When there is only one it is likely to be the Cl welchii

It has long been known that gas gangrene is more prevalent during wet cold weather than in dry cold weather or dry warm weather it was thought that contamination of the wound with mud, particularly of highly manured soil was *the* factor in the production of these anaerobic infections

So rife was gas gangrene in Flanders during the 1914-18 war and the 1939-40 fighting that the relation between highly manured soil and gas gangrene seemed established Reasonable doubt has now been cast upon this hypothesis There is no more heavily manured soil than that of the Yangtze delta upon which Shanghai stands Comparatively little gas gangrene was encountered in wounds inflicted on that soil It would appear that it is the clothing worn by the victim, rather than the soil upon which he stood, which is the major factor This theory was evolved by the following reasoning All domestic animals harbour anaerobic organisms, but the sheep is the most important source of the infection, because its wool is used for clothing The seasonal incidence of gas gangrene is in keeping with this inception, for wool clothing tends to be used in the winter months When cotton clothing is worn, such as was the case in the Italo-Ethiopian War and the Spanish War, there were but few cases of gas gangrene Medical reports concerning the fighting in the Near and the Far East are in keeping with these observations

In order to confirm the hypothesis, Maes took twelve pieces of woollen cloth, obtained from manufacturer's sample catalogues and cut them in half One half of each piece was dry cleaned and steam pressed, the other half was untreated Similarly, cotton and silk was obtained from a manufacturer's range of samples Gas forming organisms were recovered from eleven out of twelve woollen samples, whether they had been dry cleaned or not From the cotton samples such organisms were not obtained

Underclothing must also be taken into consideration For this reason wounds about the buttocks show a high incidence of gas gangrene, especially when occurring in those who have had little opportunity to bath and change, so that contamination with fæcal matter is likely

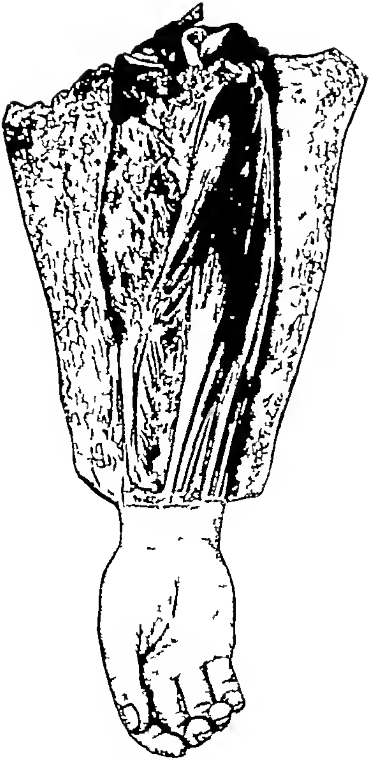


FIG 108
Gas gangrene of the supinator longus. Secondary changes in the subcutaneous tissue are shown well. (*Hull's Surgery in War J & A Churchill Ltd*)

Predisposing factors—Penetrating (syn lodging) wounds especially those caused by jagged fragments show a higher incidence of gas gangrene than do other types of wound The larger the amount of muscle damaged the greater the liability Particularly prone to gas infections are the muscular areas of the thigh calf and buttocks The upper limb is less frequently attacked The scalp face thorax and the back are affected rarely, but the retroperitoneal tissues are notorious as a site for virulent anaerobic infection when the colon or rectum has been wounded (see Chapters XLI and XLII) When for any reason there is increased tension *e g* a hæmatoma beneath strong fascia the liability to gas gangrene is increased

Decreased vascularity *e g* injury to the blood vessels or prolonged use of a tourniquet adds greatly to the risk of gas gangrene General anæmia from hæmorrhage is also an important predisposing factor

Clinical features—It is of cardinal importance to realise that the term gas gangrene is a clinical conception This being so it is perhaps well that the *gangrene* is in the forefront of the clinician's mind Actually it is the *gas* infection of the wound he seeks to diagnose

Nightingale recognizes four clinical types and this differentiation should prove helpful because their treatment and prognosis are so different The four types are —

1 Acute fulminating gas gangrene } True gas gangrene
2 Gas gangrene of muscle }
3 Gas abscess } Wounds with gas infection
4 Subcutaneous gas infection }

ACUTE FULMINATING GAS GANGRENE

In advanced cases the diagnosis is obvious The affected area is tensely swollen and cool and the khaki colour of the skin in white races is easily recognized Especially in the case of the lower limb the foot and ankle are often bluish with large blebs upon the surface There may be pyrexia although this is not great and is often absent Pain in the region of the wound (a prominent symptom in the early stages) ceases often suddenly The pulse rate continues to rise The patient who was anxious and distressed says he feels better Later still vomiting commences and the malar flush gives place to a muddy pallor Mild jaundice (Fig 109) is a common accompaniment

Prodromal signs and symptoms—It is obvious that by the time acute fulminating gas gangrene is fully established there is little to do except regret It is equally certain that there is no short cut to early diagnosis On the contrary the diagnosis has often to be made by co-relating diverse clinical findings

PAIN—There should be little pain in a wound after twenty-four hours A continuance of or an increase in pain should put the clinician on his guard Often the patient complains that the bandage or the plaster cast is too tight this should be a signal to inspect the wound

A RISING PULSE-RATE especially when combined with even slight discomfort under the plaster should be a signal to inspect the wound

LOCAL APPEARANCE OF THE WOUND—In early cases there is unlikely to be much change in the colour of the skin, although some œdema in the neighbourhood is usual Pallor rather than redness is to be expected

FIG 109
Gas gangrene septicæmia. (*British Journal of Surgery*)

CREPITUS—The discovery of crepitation is totally unreliable Even its undoubted presence is misleading Every war surgeon of experience has encountered cases where subcutaneous crepitus was present and yet when the wound was explored healthy bleeding muscle was revealed beneath

THE DISCHARGE is usually plentiful, watery and often slightly rust coloured It is most unusual for it to be bloody

THE ODOUR may prove helpful to a clinician with a well-developed sense of smell It has been variously described as musty and mousy in later cases as rotten meat As time goes on there is no doubt about the offensiveness which is due to the digestion of avascular muscle fibres by proteolytic organisms

X ray diagnosis Many gunshot and bomb splinter wounds on radiographic examination show gas shadows which are due to imprisoned air or to hæmatoma formation this is particularly the case when foreign bodies are retained On the other hand radiographs can prove helpful in confirming a doubtful diagnosis A good radiograph will show even a small quantity of gas in the tissues Sometimes a characteristic appearance is revealed by the separation of muscle fibres by linear accumulations of gas

Bacteriological examination is of unquestioned value When facilities exist no time should be lost in availing oneself of the services of the

Fig 110

Fulminating gas gangrene Note infiltration of musculature with gas and larger subcutaneous bubbles Fatal case (*James F Brailsford*)

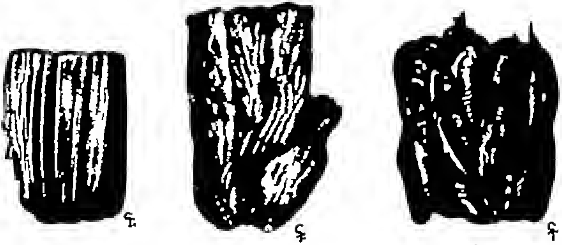
Fig 111

Compound fracture of femur Multiple air bubbles in thigh Localized surgical emphysema due to gas being forced into soft tissues (*James F Brailsford*)

Fig 112

Compound fracture of lower third of tibia and fibula with secondary gas gangrene of musculature Amputation (*James F Brailsford*) bacteriologist The finding of a specific organism is an indication for the employment of a specific antitoxin

Operative diagnosis—Provided the patient is in even moderately good condition this is an occasion where it is safer to look and see than to wait and see The appearance of muscle in the neighbourhood of the wound is a most reliable guide The changes in colour (Fig 113) are characteristic When cut anaerobic infected muscle fails to contract or does not contract vigorously furthermore it does not bleed



A B C

Fig 113—Gas Gangrene

A Normal muscle B "Red death"—note the cavitation by bubbles of gas C, "Black death." (*After Sir Cuthbert Wallace*)

PROPHYLAXIS

Primary wound excision forms the best protective measure against gas gangrene If all wounds could be attended to by a skilled operator within eighteen hours the incidence of gas gangrene would be low

Anti gas gangrene antitoxin is generally conceded to be valuable The dose recommended is 300 international units of Cl welchii 1 500 of Cl septique and 1 000 of Cl œdematiens given intravenously or intramuscularly

Sulphonamide therapy—There is no evidence that these drugs are specific against gas forming organisms but there is every reason to employ them both locally and generally at any rate they destroy some of the organisms notably streptococci which constitute a symbiosis

TREATMENT

Conservative operation—Early operation founded on an understanding of surgical pathology combined with energetic serotherapy and chemotherapy are the sheet anchors This is certainly an occasion which calls for débridement in the true meaning of the term in that it is essential to provide free drainage and remove projectiles and other foreign matter Nevertheless this is not enough *all infected muscle must be excised* The first step is to enlarge the wound in such a way that there will be free drainage of even the deepest recesses There is neither danger nor objection to large exploratory incisions but as far as possible they should always be made parallel to the long axis of the limb , on the other hand, the deep fascia should be divided transversely By this expedient tension is relieved more adequately and the tortuosities of the wound track are often more quickly visible The aperture in a muscle sheath is enlarged Damaged and infected muscle is cut away until healthy bleeding muscle is encountered The wound is followed from muscle to muscle, and wherever a fascial layer is encountered the opening must be adequate It may be necessary to resect the whole belly of a muscle Excision of infected muscle must be ruthless It is important to realize that the limit of the gas does not necessarily correspond with the limit of the gangrene , the gas often extends beyond the gangrene for as much as several inches After débridement has been completed, sulphanilamide powder is applied to the interior of the wound The wound is then packed with vaseline gauze and immobilized

CASE I—A soldier was seen three days after the right arm had been shattered by a bomb fragment the arm had been disarticulated in an ambulance train On admission he was in great pain, with a pulse of 120 and signs of toxæmia Morphia and a hot sweet drink were given, and in an hour and a half he was taken to the theatre The wound had the characteristic musty odour the skin edges were moist, swollen and purple The discharge was copious and malodorous, and extensive crepitation could be obtained The few sutures were removed, and skin flaps were retracted, after excising all unhealthy skin The pectoral, supraspinatus, infraspinatus and trapezius muscles showed extensive areas of gangrene, being greenish black in many parts All necrotic muscle was excised until healthy, bleeding and contracting muscle was found A wide exposure was obtained by suitable skin incision, but no healthy skin was sacrificed A generous quantity of sulphonamide powder was placed in the wound The operation time was one hour, and a pint and a half of stored blood was given slowly During the next five days the dressing was left undisturbed as the general conditions showed steady improvement The wound was then inspected and was found to be quite healthy The patient was discharged to the United Kingdom

CASE II—R B , *æt* 19, sustained a severe lacerated wound of the calf Primary wound excision was carried out at the C C S within a few hours, the damaged gastrocnemius muscle (medial head and belly) being excised An above knee padded plaster was applied, and he was evacuated to a base hospital on the following day (19th May 1941)

On admission the temperature was 101° F and the pulse 100 He complained of pain under the plaster Fine crepitation could be detected in the thigh immediately above the plaster The plaster was removed, revealing slight swelling of the leg and effusion into the knee joint There was a little serous discharge from the wound, and gentle pressure brought bubbles into the wound Urgent operation was undertaken The whole of the muscles on the inner side of the thigh and calf were exposed by an incision extending from the mid thigh to ankle A considerable mass of infected muscle, which did not contract on stimulation, was removed , intermuscular planes were opened up, releasing gas with a characteristic odour The infection had spread nearly half way up the thigh along the medial group of muscles On return to the ward irrigation of the wound with H_2O_2 through Carrel's tubes was carried out every quarter of an hour for three days During this time the pulse varied from 120 to 160, and the patient was obviously very ill, his facies reflecting the profundity of the toxæmia During this period he was given fresh blood followed by glucose saline Sulphapyridine in full doses was also administered with the drip In addition he received anti gas-gangrene serum 120,000 units (60,000 intravenously , 60,000 intramuscularly) Progress was highly satisfactory, and subsequently successful secondary suture of the whole wound was undertaken During the period of irrigation immobilization of soft tissues was secured by a posterior plaster shell (F G Holland's case)

Cauterization or electro-coagulation of affected muscle—Excision of large masses of muscle cannot be undertaken lightly in a patient suffering from shock and/or profound toxæmia Afonso pleads for the more frequent use of a cautery or surgical diathermy in relevant cases No infected muscle should escape the cautery If at the first attempt, cauterization is not possible it should be finished on the following day Two days after cauterization most of the necrotic tissues will be found to be dry and shrivelled like smoked meat This coagulated tissue can then be removed easily with scissors

Amputation is still the safest form of treatment in many cases of acute fulminating gas gangrene. When the infection is associated with a compound fracture, when the vascular supply to the limb is impaired, or when the infection has invaded so deeply as to make excision of muscle impracticable, a rapid amputation has often saved the patient's life.

Since gangrene extends more rapidly and to a higher level in the muscles than in the skin (Fig. 114), there is nothing to be said in favour of the guillotine amputation.

Nightingale, in a large experience of cases of gas gangrene, states that during the 1914-18 war he never did a guillotine amputation, and after a short experience of turning back flaps and leaving the wound open, he abandoned that method as the shock was too severe. He simply packed the

FIG. 114

Advanced gas gangrene of the forearm. (*Bull's Surgery in War*, J. & A. Churchill Ltd.)

wound with gauze soaked in flavine and secured the flaps in position with two sutures. In a very large proportion of cases he was able to close the wound in two or three days by delayed primary suture. Mullally says: "Never sew the flaps together: just pack the wound with gauze and bandage it firmly."

After sectioning the bone, all the muscles in the neighbourhood must be inspected carefully. If one muscle or group of muscles is affected it must be excised up to healthy bleeding muscular tissue. "In amputating for gas gangrene, if it is found that one or more muscles are gangrenous at the level of their section, do not change your plan. Finish the amputation and then split the stump widely and excise the diseased muscle." (Mullally.)

CASE III.—Corporal B., who had a simple fracture of the lower third of the femur and a compound fracture of the tibia and fibula of the same side, developed gas gangrene of the leg. Amputation was performed at the site of the femoral fracture, and a discoloured, avascular portion of the biceps muscle was excised. Sulphonamide powder was put in the wound and the skin sutured loosely. Convalescence was satisfactory.

Sero-therapy.—Provided adequate precautions are taken to avoid anaphylactic complications, the intelligent use of sero-therapy can only be in the patient's interest. Anti-gas gangrene serum should be given by the intravenous drip method, 80 to 100 c.c. of serum in 1,000 c.c. of normal saline

The injection should be administered after desensitization, so slowly that it takes up to one to one and a half hours to complete Two such doses are often required The amount of anti-gas gangrene serum to be injected intravenously in established cases during the first four to five days is 400 c c (Guleke)

When the causative organism has been identified the appropriate monovalent serum can be used

Chemotherapy—Evidence is accumulating to show that locally sulphathiazole is the most effective compound in all cases, and sulphanilamide is better than sulphapyridine in the (frequent) B welchii infections (Hawking)

It is recommended that immediately before an operation for gas gangrene combined serum and sulphonamide therapy may protect the patient against an exacerbation of the infection

MASSIVE GAS GANGRENE OF MUSCLE

In many instances the gangrenous process is localized more or less to one muscle or group of muscles this indeed, is a characteristic feature of gas gangrene Occasionally the gangrenous process is surprisingly limited Nightingale cites a case where the infection was confined to the infraspinatus and this muscle was removed in a semi-liquid condition by simply wiping it off the scapula with a swab leaving the bone as bare as a skeleton When gas gangrene is limited to a muscle or group of muscles patients are not so desperately ill as those in group 1 but if adequate treatment is delayed they usually soon become profoundly toxic

GAS ABSCESS

Gas abscess is common when the missile has lodged in a wound and frequently gas can be seen bubbling out Patients with this variety of anaerobic infection are seldom seriously ill

SUBCUTANEOUS GAS INFECTION

The subcutaneous tissues are involved without infection of the deeper planes There is a crepitant area round the wound with more or less widespread khaki discoloration of the skin this may extend as much as 10 in beyond the wound Skin discoloration does not imply that there is gas gangrene in all the muscles beneath Unless this is realized amputation may be undertaken when it is unnecessary If the wound is enlarged it will be found that the discoloration of the skin bears little relation to the extent of the muscular involvement After excising discoloured muscle in the usual manner it is only necessary to make multiple incisions into the discoloured skin These incisions should not penetrate the fascia, this is an important point

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CHAPTER XIV

THE X-RAY TREATMENT OF GAS GANGRENE

X RAYS have been used in the treatment of gas gangrene in America for the past thirteen years but it was not until quite recently that they were employed for this purpose in England. The first advocate of this treatment was J. F. Kelly of the Creighton University Omaha He treated his first case a patient of J. R. Davers, in August 1928 and was so impressed by the result that he treated seven others and published these eight cases as his first series. He has reported a number of his own cases since then and collected data on a large number that were treated elsewhere as the result of his work His claims have been supported by a number of others, notably R. L. Sewell of the University of Rochester New York. Over 200 cases have now been reported with a mortality of less than 10 per cent Although the statistical value of such a group collected over a wide field is not very great a study of this literature leaves one in little doubt that X rays are worthy of a more extended trial in the treatment of this infection.

PLACE OF X RAYS IN TREATMENT SCHEME

Radio therapy has been used in conjunction with other measures in a conservative treatment scheme surgery being limited to the cleaning of foreign material from the wound and the removal of any hopelessly damaged tissue that separates early Kelly expresses the opinion that amputation should never be performed solely on account of the presence of gas gangrene but only if the extent of the injury makes it absolutely necessary The results of any form of treatment must be judged not only by the mortality rate but also by the amount of mutilation caused The advocates of irradiation maintain that it not only reduces the mortality but saves many a limb

Great stress has been laid on the fact that X rays should be regarded as an aid in the treatment and not as the sole method of attack Tetanus antitoxin is given in every case and in some either serum or sulphonamide Sewell found X rays to be of more value than sulphanilamide but used both together in a number of cases

X rays have also been used as a prophylactic measure in patients with compound fractures or extensive lacerated wounds without the development of gas gangrene in a single case so far W J Mowat has treated a number of such patients in Nottingham He found that there was a marked and rapid reduction in the traumatic œdema and great relief of pain within the first twenty four hours of starting treatment

Technique—The object of treatment is to deliver a small dose to the whole volume of tissue involved at frequent intervals over a short period The dose given at each treatment should not be more than 100 *r* (usually 50 to 75 *r*) The exact dose is not of any very great importance providing that this order of dosage is employed the important factor is the correct spacing of the treatments When irradiating large volumes of tissue with small doses for a short period it is not necessary to attempt such precision in positioning and uniformity of dosage as is aimed at in malignant disease, where smaller volumes of tissue are being given a high dose over a longer period The therapy plant should be carefully calibrated and the output checked from time to time When the dosage rate with backscatter for a fixed focal-skin distance is known any surface dose required may be given by timing the treatment with a stop-watch An applicator is helpful, as it indicates the direction and spread of the beam and fixes the focal-skin distance Each treatment takes only a few minutes with these small doses

The number of fields used will depend on the extent of the infection and the thickness of the part involved If a considerable depth of tissue must be irradiated a more even dose will be given to the whole volume if fields are placed on either side of the limb or trunk It is usual to give two treatments each day, but for the more acute cases six-hourly treatments for the first twenty-four hours may be an advantage Treatment should continue for a minimum of three days but if extended over a longer period the exposures should be reduced to one a day When a large volume is being irradiated the duration of treatment should not exceed one week or the dose 1 000 r per field Large doses of X-rays in the presence of infection do much more harm than good

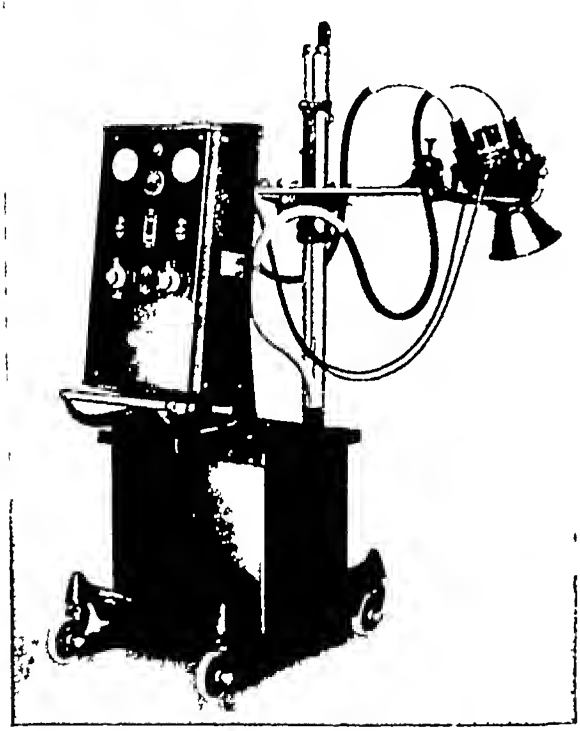

FIG 115

Mobile high voltage X-ray therapy apparatus for bedside treatment

The actual technique employed will depend upon the apparatus available and the individual requirements of the case A treatment scheme might be carried out as follows Two fields 25 cm in diameter on either side of the thigh 18 cm apart 140 kV 0·5 mm Cu filter, 30 cm focal-skin distance, 75 r to each field (surface dose with backscatter) twice daily for three days Under this particular set of circumstances the dose on the skin on either side would be approximately 80 r and the dose at the mid-point between the fields 30 r

Apparatus—The first cases of gas gangrene irradiated were treated with a mobile X-ray unit designed for diagnostic work Such apparatus is unsatisfactory because of the very limited penetration of the radiation obtainable It is most undesirable to take an acutely ill patient twice a day to an X-ray department, so if the best results are to be obtained it is essential to have adequate mobile X-ray therapy apparatus Apparatus of this type is now available It does not seem improbable that such units will one day form a part of the standard equipment for the treatment of infective conditions in any large general hospital. Unfortunately no English manufacturer yet makes a suitable plant though several state that they are prepared to do so at short notice should the demand arise. Fig. 115 shows an American mobile X ray therapy apparatus similar to one in use at the Royal Cancer Hospital. This apparatus operates at 140 kV.

It is clear that a higher kilovoltage, a greater focal skin distance and more filtration than those referred to in the technique described above would enable the radio therapist to give a more even dose to a large volume. There are grave technical difficulties in making reasonably light and mobile apparatus of this type, and even if available the advantages over existing plants would not be very considerable for this particular purpose. The present apparatus is at least a great advance on the mobile diagnostic units which were used at first, and used with some success.

GENERAL CONSIDERATIONS

A theoretical basis of the action of X rays in infections has not yet been accepted. A large number of infective conditions are favourably influenced by small doses of X rays, and in some of the more acute cases the effect is noticeable in a matter of a few hours. Such a rapid response with weak doses strongly suggests that the effect is produced by an action on highly radio-sensitive tissue. The white blood cells, particularly the lymphocytes, are amongst the most radio-sensitive cells in the body and in fact break down so readily that the production of a severe leucopenia is one of the main obstacles in the way of the successful treatment of deep-seated malignant tumours by X rays. It has been suggested that the action of X rays in infections is due to the breakdown of white blood cells and the consequent liberation of defence substances in the irradiated tissues.

As a general rule, the more acute the infection the smaller should be the individual doses of radiation, the more frequently should treatment be given and the shorter should be the total period of treatment. The sooner irradiation is started the more effective is it likely to be.

More work is required before we are able to establish the principles of the action of X rays in gas gangrene or are in a position to judge its true value. It is possible that the type of case which recovers with X ray treatment is not true gas gangrene but anaerobic cellulitis as suggested by Qvist, but there is sufficient evidence in its favour to warrant a more extended trial of this method as an aid in the treatment of gas gangrene.

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SECTION IV

WOUNDS SPECIAL CONSIDERATIONS

CHAPTER XV

SURGICAL MATERIALS AND DRESSINGS

In order to avoid cross infection of wounds B M Dick has introduced an excellent system of separate dressings for each patient They are packed and sterilized in 50 cigarette tins

Sterilization of dressings—Especially at a time when the breakdown of gas and electricity supplies are frequent absolute proof that drums of dressings have been sterilized is imperative Professor Willan describes a simple and effective method which has been used for thirty years at the Royal Infirmary Newcastle-on-Tyne Every batch of materials for sterilization is subjected to the test Into every drum is placed a special paper impregnated with a preparation of iodine The test paper is placed in the middle of the parcel of articles to be sterilized If the middle of the parcel (the site of the test paper) has reached a temperature of 113 C the test paper will be found to be decolorized and the printed word sterilized will appear on a white background If the heat required has not been reached the test paper will retain its brownish black colour or perhaps be only partially bleached (Fig 116) The papers in bundles of 100 can be obtained from H F Crawford Colbeck Hall High Friar Street Newcastle-on-Tyne

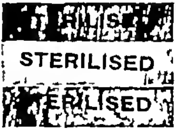


Fig 116

Appearance of test papers. A, Before use B After use if temperature at site of the test paper has reached 113 C C If the required heat of 113 C has not been reached.

Sterilization of rubber gloves—Now that rubber surgical gloves are of an inferior quality and delivery of supplies is uncertain their conservation is highly important Owing to the friable and unsatisfactory state in which autoclaving leaves these war time gloves some surgeons have reverted to sterilization by boiling Professor Willan after a series of experiments has shown that surgical indiarubber gloves can be efficiently sterilized in an autoclave at a pressure of 10 lbs for thirty minutes and retain their vitality Pressures higher than this cause the rubber to perish The test shows that gloves sterilized in this way by the dry method last longer than those sterilized by the wet method but the pressure must never be more than 10 lbs

TOPICAL APPLICATIONS AND DRESSINGS

VASELINE GAUZE DRESSINGS

Vaseline gauze packs and vaseline gauze drains are being used extensively The one objection is the greasiness of vaseline which once it has got on the surgeon's gloves impedes the nimble use of his fingers Chemists are endeavouring to produce a non-greasy substitute By packing the wound with vaseline gauze we ensure that there are no pockets from which pus cannot escape freely to the surface The wound is packed lightly with vaseline gauze and the surrounding skin is smeared with vaseline to protect it from the irritating effects of the purulent discharge from the wound This method is employed widely in the closed plaster technique

Vaseline gauze drains may supplant rubber tubes, they have the advantages that they do not require to be turned or shortened and are unlikely to cause pressure necrosis

Method of preparing vaseline gauze—Pieces of four thicknesses of gauze size 10×8 in are folded in the manner shown in Fig 117 These are piled in

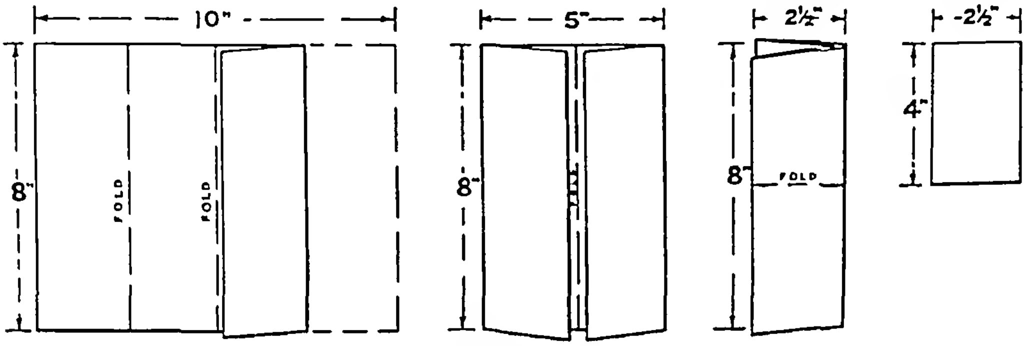


Fig 117

Method of preparing vaseline gauze packs Pieces of four thicknesses of gauze, 10×8 in, are folded inwards thus

a tin box—any reasonably well-made tin box will do—together with assorted rolls of ribbon gauze (2-in 1-in and ½-in ribbon gauze have been found to be the most convenient sizes) The box is more than half-filled with vaseline It is essential to have enough vaseline to cover the gauze and to soak it thoroughly The tin lid is put loosely on and the tin is autoclaved for twenty minutes at 15 lbs pressure As the box is removed from the autoclave the lid is affixed firmly and sealed with adhesive tape and the box is labelled with the date of the sterilization and the initials of the sister responsible The box is resterilized after each time that it is opened, or at weekly intervals if it is not used Before the vaseline gauze is used the box should be warmed on top of a sterilizer or a radiator to soften the vaseline and to make the gauze more easily worked

TULLE GRAS

Tulle Gras being manufactured in France, is now unobtainable As this is a very useful inert dressing and is often employed in skin grafting by Thiersch's method the details of its preparation can be included with advantage

The following method of manufacture will be found to be satisfactory and it can be carried out by the dispenser or the theatre sister The material used is mosquito netting $\frac{1}{16}$-in mesh it should be washed to remove dressing Pieces of the netting 4 in square are placed in tins of the same size until the tin is two-thirds full A mixture of 98 parts soft paraffin

1 part balsam of Peru and 1 part halibut oil is made and stirred well Six or 7 lbs of the mixture can be dispensed in large tins

With a spatula, a thick layer of the mixture is placed in each tin. It is difficult to estimate how much is needed to saturate the net but an excess can be poured off after sterilizing The tins are placed on trays in the sterilizer They are sterilized at 15 to 20 lbs. pressure for fifteen minutes. The heat is turned off and the boxes allowed to cool in the closed sterilizer On no account must the pressure be allowed to fall suddenly or the grease will bubble and overflow from the tins. The tins are removed when the pressure falls to normal. If there is an excess of grease this can be poured off until the dressing is just covered. The lids are replaced on the tins, which are allowed to cool before being sealed with strapping

Several British firms are now manufacturing dressings of this type such as Nonad Tulle (Allen and Hanbury) Optrex Tulle (Thackray) and Jelonet (T J Smith and Nephew Ltd) Nonad Tulle with Chlorophyll is an excellent preparation of which we have had satisfying experience

D N Matthews finds Tulle Gras is ideal for the treatment of all raw surfaces and advises that a local anæsthetic be added to the oleaginous mixture One per cent powdered Decicaine is the most efficient but this adds about four shillings to the cost of each tin It was found that the addition of 0 1 per cent of powdered Percaine base was nearly as effective and added only a few pence to the cost of each tin In the concentration of 0 2 per cent it occasionally caused some local irritation and tingling Any increase of temperature above 100 C may decompose the anæsthetic and therefore must be avoided in sterilization

COD-LIVER AND OTHER FISH OIL DRESSINGS

These were very popular for a time but it is probable that the good effects of the cod liver oil are purely mechanical and the same can be achieved by vaseline without the malodour The vitamins contained in fish oil viz A and D have been shown to have no effect on wound healing Odelberg employed packs impregnated with cod liver oil in conjunction with the closed plaster method and was very favourably impressed with his results

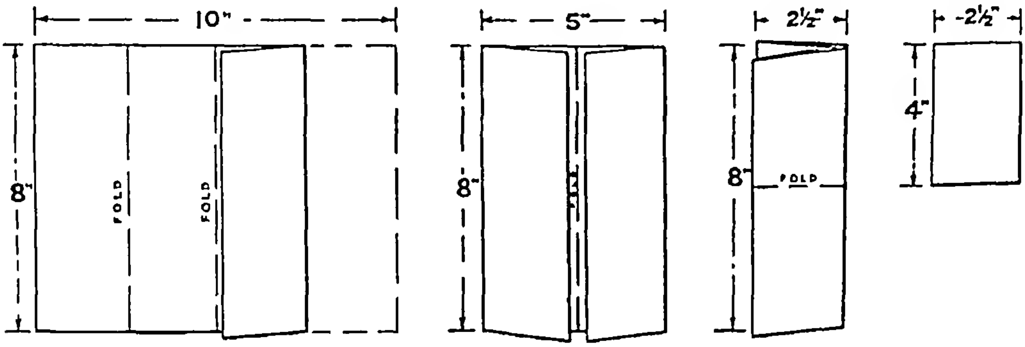
OSMOTIC " DRESSINGS

The aim is to create a flow from the wound to the dressing For many years a saturated solution of magnesium sulphate has been used for this purpose Sodium sulphate is even better A 10 per cent solution of sodium sulphate with 1 1 000 acriflavine is probably the most useful of all in this group of solutions The acriflavine does not interfere with the osmotic properties of the sodium sulphate

Many advocates of these solutions apply them on cotton wool which is soaked in the solution. They say that if the cotton wool is soaked properly particles do not adhere to the wound This may be so but we think it wiser to employ gauze as the vehicle The gauze is packed lightly into the wound, being thoroughly wet with the solution at the time of introduction The covering can consist of (a) flexible adhesive plaster or (b) a bandage over oiled silk or grease-proof paper The dressing should be left undisturbed for at least twenty four hours endeavouring to produce a non-greasy substitute By packing the wound with vaseline gauze we ensure that there are no pockets from which pus cannot escape freely to the surface The wound is packed lightly with vaseline gauze and the surrounding skin is smeared with vaseline to protect it from the irritating effects of the purulent discharge from the wound This method is employed widely in the closed plaster technique

Vaseline gauze drains may supplant rubber tubes, they have the advantages that they do not require to be turned or shortened and are unlikely to cause pressure necrosis

Method of preparing vaseline gauze—Pieces of four thicknesses of gauze size 10×8 in are folded in the manner shown in Fig 117 These are piled in



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IRRIGATION OF WOUNDS

Because it fails to provide both tissue support and appropriate immobilization of the injured part it is now generally agreed that there are but few indications for the treatment of a wound by irrigation. We should not however blind ourselves to the fact that wound irrigation proved a great advance during the 1914 18 war and in spite of the methods which have supplanted its frequent use there are still well-defined indications which may be summarized as follows —

1 When owing to anatomical or other considerations wound excision has been imperfect free drainage with wound irrigation offers a prospect of the prevention of uncontrollable sepsis
2 When it is almost certain that there will be pocketing which cannot be remedied
3 When it is known that dead tissue will have to separate
4 As a preparation for secondary suture (see Chapter XVIII)
5 In cases of retroperitoneal infection associated with wounds of the large bowel

Technique—In the original Carrel Dakin method several perforated rubber tubes are attached to a glass distributor with the idea that by this means the irrigating fluid is dispersed evenly throughout the wound In actual fact this is not so the injected fluid pools in the neighbourhood of one tube A much better method is to dispense with the distributor altogether Each tube for the irrigation of wounds is prepared as follows —

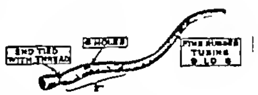

Fig 118

A piece of fine rubber tubing 9 in. long is prepared as shown and used for the irrigation of wounds.

A piece of fine rubber tubing 9 in long of a size which fits conveniently on to the nozzle of a record syringe is fashioned thus one end is tied off with thread and six small holes are cut with scissors in the two inches next to the tied end (Fig 118) The tube is laid in the depths of the wound and fixed to the skin with silkworm gut sutures The wound is packed lightly with gauze wrung out of hydrogen peroxide and covered with abundant wool leaving the end of the fine rubber tube projecting from the dressings The sister in-charge is instructed to inject 3 c c of hydrogen peroxide down the tube every three hours Each irrigation tube is injected independently

SOLUTIONS WHICH MAY BE USED FOR WOUND IRRIGATION

Hydrogen peroxide—This is particularly valuable when the presence of anaerobic infection is suspected, *e.g* in the case of retroperitoneal wounds

Eusol—12 5 gm of bleaching powder is added to 1 litre of water and shaken then 12 5 gm. of boric acid is added and again shaken. The solution is allowed to stand for some hours and is then decanted Eusol contains the equivalent of 0 27 per cent of HClO hypochlorous acid Eusol will keep for a few days only the solution should therefore be prepared frequently

B.I.P.P.

Rutherford Morison obtained astonishing results with B I P P in cases of well-established infection. Sir Charles Gordon-Watson thinks it would be reasonable to give this method a re-trial, particularly in late cases where débridement is indicated. Sir Charles recalls hundreds of cases treated by the B I P P method in the 1914-18 war with signal success, the failures were largely due to incorrect technique, for instance, leaving large quantities of B I P P in the wound.

Morison claimed that the therapeutic effect of B I P P was due to nitrous oxide liberated from the bismuth subnitrate, which acts upon the iodoform, thus liberating a constant flow of free iodine in the wound. Professor Willan says that the surgeons who have not met with success are those who have tried to improve upon Morison's procedure. Morison gave a detailed technique, the outside of the wound was to be washed with a solution of 1 : 20 carbolic acid, the inside of the wound with spirit vini rect only. The B I P P was then smeared on very lightly and evenly. The dispensing of B I P P is an important detail. It should be gritty when rubbed between the finger and thumb. If there is too much paraffin it will not adhere to the wound surface. B I P P in collapsible tubes is useless. It should be stored in porcelain containers.

Z I P P

This is a paste containing :—

Zinc oxide	1 part
Iodoform	2 parts
Liquid paraffin	2 to 3 parts

(Mixed to the consistency of clotted cream.)

Connell and Buchanan claim that it has considerable advantages over B I P P. For some reason, iodoform poisoning, the bugbear of the B I P P method, never occurs when Z I P P is used, and bismuth poisoning cannot result because the paste contains no bismuth. When wounds are packed with gauze impregnated with Z I P P the closed plaster method is accompanied by a lesser degree of stench. Connell advised and practised the treatment of wounds with Z I P P in tropical Africa, and in a personal communication he states that he and his colleagues have found Z I P P most suitable in war casualties occurring in the Near East. Vaseline has obvious disadvantages in hot climates.

ALLANTOIN

Maggot therapy is dealt with in Chapter XVI. Attention is directed here to Allantoin which purports to be an accelerator of wound healing. Existent in allantoic fluid, in the Comfrey root and in the excretions of certain maggots, Allantoin appears to facilitate the removal of necrotic material, to exhibit cell-proliferating properties and to promote healthy granulations. This substance can be obtained as (*a*) 4 per cent. Allantoin with 96 per cent. sulphanilamide and (*b*) pure Allantoin. The latter is used only in clean wounds. Both are in powder form, supplied by Genatosan Ltd.

At the time of writing by far the most popular method of wound treatment is the introduction of sulphanilamide powder followed by a vaseline gauze pack Indeed this may be said to have become the standard method and an alternative is employed only when this method has failed to give desired results

Prevention of secondary infection support to the damaged tissues and efficient immobilization of the injured member are the guiding principles in wound repair Important as these principles are the surgeon must not become oblivious to other points of view which in the main concern the patient as a whole

OTHER FACTORS IN WOUND HEALING

Particularly in cases of long standing suppuration a periodic blood count and hæmoglobin estimation is advisable A blood transfusion should be given if necessary

Vitamin K should be given if there is recurrent bleeding from granulation tissues

Vitamin C—It has been proved conclusively that a subscurvy state delays healing and predisposes to disruption of abdominal wounds Every patient whose tissues are endeavouring to repair a wound should receive an adequate intake of vitamin C *e.g* fruit and green vegetables If it is impossible to supply the vitamin in this form ascorbic acid can be prescribed the full dose of which is 1 000 mg per day for three days Afterwards to maintain saturation 100 mg per day is given for about three weeks while the wound is healing

Protein v carbohydrate diets—A high protein diet hastens the repair of wounds It is therefore desirable that the patient should receive a high protein intake from the commencement of treatment Milk grated cheese egg albumen and pounded fish are all suitable articles of food as soon as the patient s condition permits

Œdema of the wound inhibits healing If this is realized the following measures to prevent the occurrence of œdema will occupy the surgeon s attention —

(*a*) *General*—Dilution of the large molecular content of the blood sets up intercellular œdema The danger of over administration of intravenous saline has already been emphasized as a cause of intra-cellular œdema by producing dilution of the large molecule-content of the blood If however there is reason to suspect that the œdema is the result of protein anæmia from long-continued low nitrogen intake a plasma or blood transfusion will tend to remedy the deficiency

(*b*) *Local*—When possible in order to minimize œdema in the neighbourhood of a healing wound the aid of gravity should be invoked If sutures particularly deep sutures are causing local œdema it is often advisable to remove all or certain of them and to substitute corsettage to support the wound

CORSETTAGE

Corsettage has a great field of usefulness in the treatment of wounds The term was used by the French surgeons during the 1914 18 war and the principles involved were instigated by British Army surgeons notably

Dakin's solution—Dissolve 37 6 gm of sodium carbonate in a litre of water, and mix gradually with 18 8 gm of chlorinated lime The liquid is well shaken for about half an hour, decanted and filtered, in the filtrate is dissolved 4 gm of boric acid The solution contains 0 5 per cent of available chlorine and will keep for about a week

Chloramine—Sodium paratoluene sulphochloramide ($CH_3C_6H_4SO_2NNaCl, 3H_2O$), sometimes known as chloramine-T, is an odourless substance freely soluble in water and contains 12 6 per cent of chlorine A watery solution of chloramine will keep for a considerable time In the presence of organic matter it gives up chlorine fairly rapidly, but not so rapidly as does a solution of hypochlorous acid or hypochlorite A stock solution of 2 per cent chloramine will keep for a considerable time It is used in strengths between 2 and 0 2 per cent, most commonly 0 5 or 1 per cent A solution of chloramine has four times the germicidal power of an equimolecular solution of hypochlorite, but the other two have the advantage that the substances needed for making them can be obtained almost anywhere

As these substances all give up chlorine rapidly when they come into contact with proteins, and as there is abundant protein in any wound in addition to bacteria, irrigation should be carried out frequently so that the antiseptic action may be sustained Five cubic centimetres of the compound being used should be injected down each tube every two hours This treatment should not be continued for more than a few days, as the wounds tend to become waterlogged

OPEN-AIR TREATMENT

When a wound is nearly healed and only a small granulating surface remains to be epithelialized, it can be left uncovered and exposed to the air under a bed-cage Wounds treated in this way often heal with surprising rapidity

ANALYSIS OF THE VARIOUS METHODS

It will be appreciated that the modern method of infrequent dressings has minimized the danger of cross-infection besides lessening the labour of the surgical staff There are no definite indications for the use of this or that method of treating a wound, it is a matter of individual preference and common sense For instance, if one method is not giving expected results, benefit may accrue from changing to another In recent years considerable changes have occurred in the general trend of wound treatment The surgical profession, as a whole, has abandoned the application of antiseptics to wound surfaces Antiseptics are looked upon as "decelerators" of healing and strong antiseptics as protoplasmic poisons The army of enthusiasts for B I P P has been reduced to a corporal's guard Some have carried this change too far The more moderate, which constitute the majority of the profession, still find use for mild antiseptics, of which a 0 1 per cent solution of acriflavine is by far the most popular Garrod has shown that this solution causes very little, if any, damage to tissues The emulsion of acriflavine of the B P C, he says, is inert because of the presence of oil The proper vehicle for the application of antiseptics to the tissues is water, and the solution should be isotonic

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John T Morrison, who wrote as follows 'Strips of strapping are applied to the skin with a row of hooks stitched along the edges nearest the wound (Fig 119) The wound edges are then drawn together by means of thin elastic tubing, the wound surface being protected by a dressing The well-known elasticity of the skin is strikingly revealed, and in two or three days it is frequently possible to close what at first looked like a hopeless gap"

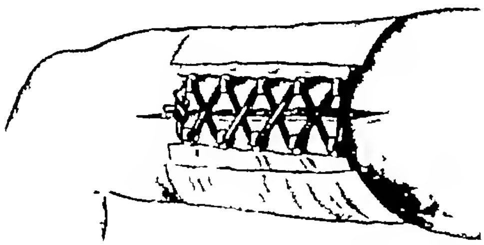


Fig 119
Corsettage of a wound

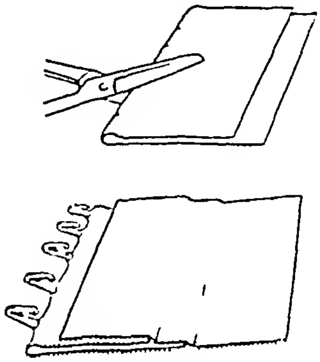


Fig 120
Kelly's method of fixing dressmaker's hooks to adhesive strapping

Methods of constructing wound corsets have been improved

(*a*) *Sir Robert Kelly's method* — A piece of strapping is folded longitudinally not quite in the middle line, its sticky side outwards Nicks are made with scissors (Fig 120, A) in the fold, just large enough to allow a dressmaker's hook, but not its flattened arch, to be pulled through When enough hooks have been inserted a second piece of strapping is placed over the first, sticky side down (Fig 120, B) The strapping is fixed along each side of the wound and the hooks are laced with a length of stout silk or fine rubber tubing

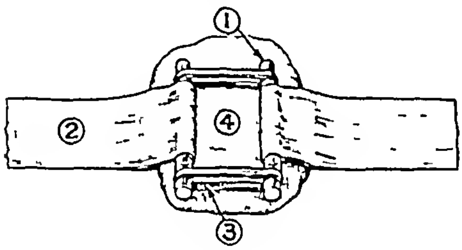


Fig 121
Method of fixing a dressing which requires frequent changing (*After Learmonth*)

1 Glass rods
2 Strips of flexible plaster folded round the glass rods so that the adhesive surface does not come into contact with the dressing
3 Rubber bands
4 Dressing

(*b*) *Learmonth's method* — Strips of adhesive plaster are folded round the glass rod in such a way that the adhesive surface does not come in contact with the dressing When the adhesive plaster has adhered to the skin, strong rubber bands are applied as shown in Fig 121

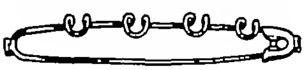


Fig 122
Sir William Wheeler's safety-pin with hooks for corsettage

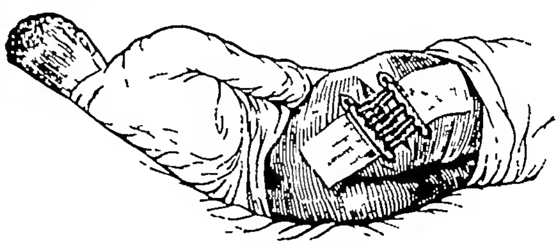


Fig 123
The same applied

(*c*) *Sir William Wheeler's safety-pin* (Fig 122) is easily and quickly inserted into strapping (Fig 123) (*d*) *Laparotomy corsets* are designed for supporting abdominal wounds and are certainly most effective Laparotomy corsets should always be affixed in cases where a laparotomy incision shows evidence of infection This is a great safeguard in preventing bursting of the wound This is common knowledge but what is not so well known is that ready made laparotomy corsets (Fig 124) can be —

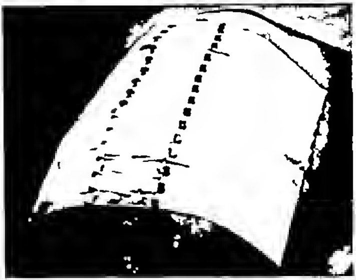


Fig 124

Laparotomy corset in use

1 Adapted to the contour of the abdomen by cutting as shown in Fig 125 A and B with a strong pair of scissors
2 Also by cutting them appropriately they can be adapted for any wound

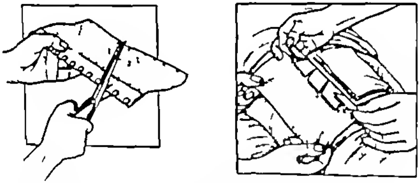


Fig 125

A, The "corset," if cut as shown, can be adapted to the contour of the abdomen. B The "corset" after cutting The adhesive surface is applied evenly to the lateral abdominal wall and held until it has adhered firmly

By the early and intelligent use of corsettage in appropriate cases it is no exaggeration to say that often the final closing of the wound is expedited by many weeks and the number of wounds requiring secondary suture is reduced considerably

THE "WATER SHED" DRESSING

The "water-shed" dressing is used to separate two wounds for instance a laparotomy incision from a caecostomy or colostomy or what is even more important in the case of gun-shot wounds in the vicinity a suprapubic bladder incision from a colostomy (Fig 127) If the two wounds are dressed at different times it ensures that there is absolutely no contamination from one wound to the other, even if the dressing be done by a comparatively inexperienced person

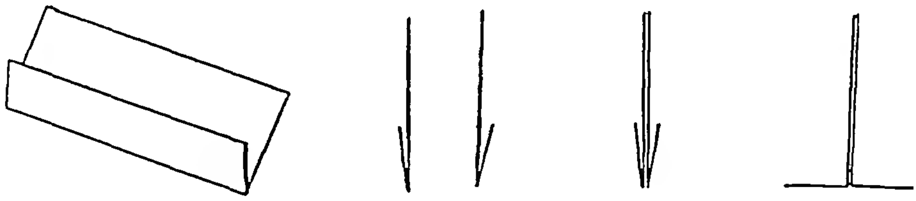


Fig 126

Making a "water shed" A, Method in which the strips of adhesive plaster are folded B, Approximation of the strips held by the surgeon and assistant C, The strips approximated D, The "water shed" as applied to the abdomen

Non-flexible adhesive plaster is used A strip of broad adhesive plaster about 6 in long is taken by the surgeon and a piece of exactly similar length by the assistant Facing one another, and working independently but simultaneously, both surgeon and assistant fold their piece of plaster longitudinally (Fig 126, A) The surgeon now approaches the assistant, and the strips of plaster are placed back to back (Fig 126, B and C) The surgeon then takes the two pieces, the backs of which have adhered to one another, and applies the "water-shed" to the abdominal wall between the two wounds (Fig 126, D) Fig 127 shows the "water-shed" in action In addition to preventing fæcal contamination of the laparotomy or cystostomy wound, it serves to remind the nurse that the two dressings must be dressed separately

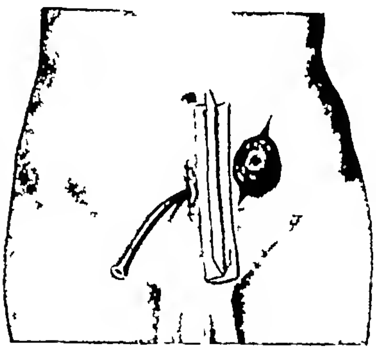


Fig 127
The "water-shed" in action

Flexible adhesive plaster bandages—In a small minority of cases the patient's skin is irritated by the use of adhesive plaster, and its removal may cause pain These disadvantages can be minimized by correct technique

1 The skin must be shaved before adhesive plaster is applied

2 Adhesive plaster should not be applied to skin which has been recently painted with iodine If iodine is used at the end of the operation, only the immediate neighbourhood of the wound—the area to be covered by the gauze—is painted

3 The removal of adhesive plaster is aided by sponging it off with a piece of wool moistened with methylated ether, or, better still, one of the proprietary preparations, Zoff (T J Smith & Nephew) or Antihæsin (Allen & Hanbury)

For abdominal incisions—Small lateral operation wounds are dressed with gauze No wool is used and the gauze is covered with a length of flexible adhesive plaster The paramedian incision is dressed with overlapping strips of the plaster (Fig 128) Experience has shown that this method of bandaging laparotomy incisions near the mid line is the most comfortable. I believe that this comfort is due mainly to the firm support which the adhesive plaster gives to the abdominal muscles and to the absence of cumbersome dressings The support also aids the rapid healing of the wound

Fig 128
Paramedian incision dressed with overlapping strips of flexible adhesive pla ter

Three points need special attention in the application of the adhesive plaster to the abdominal wall —

1 The plaster should extend from loin to loin starting and finishing well back two-thirds of the circumference of the body is covered

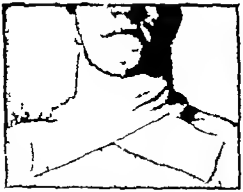
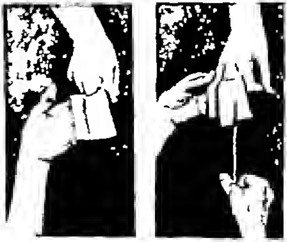


Fig. 129
Flexible adhesive plaster used in a case of a wound of the neck.



A B

Fig 130
Method of applying and cutting a plaster jacket for the finger A length of plaster is applied to the palmar aspect of the finger folded over the tip and back over the dorsal aspect. The excess on the sides is pressed together and the result is shown in A. The excess on the sides is cut away (B), leaving a neat jacket.

2 Each succeeding strip of plaster should overlap the previous strip by one third

3 The lower strips should be applied firmly with the plaster slightly on the stretch. The upper strips should not be applied on the stretch lest the freedom of the respiratory excursion of the bases of the lungs be restricted.

OTHER EXAMPLES OF THE USE OF FLEXIBLE ADHESIVE PLASTER—An example of the use of flexible adhesive plaster in the treatment of a wound of the neck is shown in Fig 129, and of its use as a finger dressing in Fig 130

Only a few examples have been given of the use of adhesive plaster in the dressing of aseptic wounds, it can be used for almost any such wound This method of fixing dressings is so satisfactory that I consider it should be used almost as a routine

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Other Factors in Wound Healing

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CHAPTER XVI

MAGGOT THERAPY IN INFECTED WOUNDS

GENERATIONS of surgeons have encountered wounds infested with maggots From time to time they have recorded their observations and usually these include amazement that the presence of maggots is not detrimental to healing indeed, the infested wounds were often so clean as to cause comment So impressed was Baron Larrey by this feature that during the Napoleonic wars he drew attention to the so-called healing power of maggots During the 1914-18 war the attention of an American surgeon W S Baer was arrested by the obvious beneficial action of maggots in destroying infection. He it was who introduced and elaborated planned maggot therapy

Maggots in a wound were and still are looked upon with disgust and as a sign of utter neglect Baer came to regard them in another light in this way In 1917 two soldiers with compound fractures of the femur and large flesh wounds came under his care after seven days exposure in no man s land At that time the mortality of compound fractures of the femur was about 75 per cent and yet these men were in comparatively good condition and their wounds although crawling with thousands of maggots were filled with pink granulation tissue The character of these wounds says Baer made such an impression upon me that I could not help revolving the question in my mind for the next ten years until I finally decided to put the observation made on the battle field into practical use This was the birth of maggot therapy

Notwithstanding numerous favourable comments on the employment of maggots in infected wounds their extended use has been hindered owing to certain æsthetic and technical difficulties Both of these can be overcome

Surmounting æsthetic difficulties—After the rationale has been explained to them no patients under my care has refused the application of maggots As a matter of fact the patients have displayed a keen interest in the work and were extremely co-operative The principal objection comes from the nursing staff but I believe that if the absolute sterility of these maggots is explained and methods of their culture demonstrated, this difficulty could soon be overcome

BREEDING THE MAGGOTS

Source of laying stock—A piece of meat is hung up in the open. It is then placed with the accompanying eggs in a jar Unless the jar is half filled with gauze the meat liquefies and drowns the maggots Maggots will grow to maturity and pupate in the gauze the entire period occupying seven days at room temperature The pupæ are shaken out and tied in gauze bags for convenience in handling They are placed in a covered jar and allowed to hatch, the period required for hatching being from five to seven days at room temperature Many flies hatch out Maggots of the Texas screw-worm fly (*Chrysomyia macellaria*) (Fig 131, A), found throughout the United States of America and southern Canada during the summer months, were first used, but it was found that the Texas screw-worm maggots burrowed too deeply and got out of control The best results have been obtained from maggots of the sheep blow-fly (*Lucilia sericata*) (Fig 132), common in Europe and North America, although maggots of the blue-bottle fly (*Calliphora erythrocephala*) (Fig 131, B), also widely distributed and prolific give excellent therapeutic results [1]

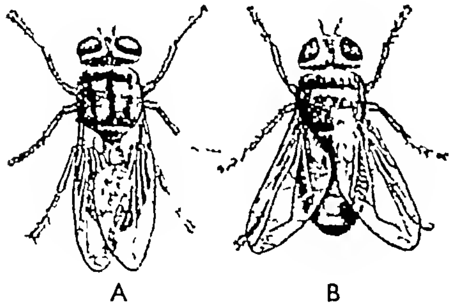

Fig 131
A, Texas screw worm fly (*Chrysomyia*)
B, Blue-bottle (*Calliphora*)

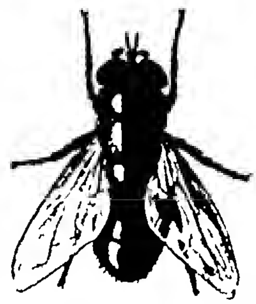

Fig 132
Sheep blow fly
(*Lucilia*)

Rearing flies—In order to obtain large quantities of eggs, cages can be used A cage measuring 30×30 in can be made of perforated zinc and is capable of holding 2 000 flies (Fig 133) The door slides in grooves and the opening is covered with a gauze sleeve For flies to survive it is essential that they have plenty of water which is supplied in a glass tumbler filled with gauze upon which the flies can alight Their food consists of lumps of sugar, a mixture of orange juice and egg poured on gauze in a Petri dish, and lean meat A continuous supply of meat seems to increase the fecundity of the flies During the winter the flies are kept in a steam heated room, the temperature of which is maintained at 70° F No attention need be paid to the question of humidity or ventilation Flies thrive and lay eggs under these conditions

Collecting the eggs—The eggs are collected every four to six hours, at which time a fresh supply of meat is placed in the cage If the eggs are collected at longer intervals, some of them will hatch, and as it is impossible to sterilize maggots and somewhat difficult to separate them from the eggs a batch of eggs may become contaminated The eggs are picked off the meat with a toothpick, placed on damp filter paper, and can be stored in an ice box for as long as six hours

Separation of the eggs—Satisfactory results are obtained by rolling the clumps of eggs against the side of a test-tube half-filled with a 0 85 per cent solution of sodium chloride, using a swab stick The eggs, thus separated, sink to the bottom of the tube The importance of the complete separation of the eggs cannot be over-emphasized Most of the failures in sterilization are due to incomplete separation of eggs

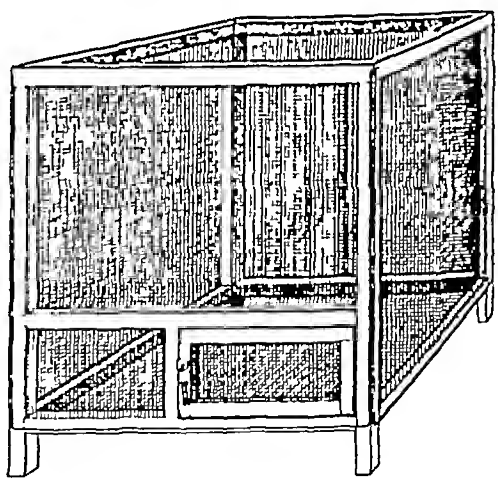

Fig 133
A cage measuring 30 × 30 in will accommodate 2,000 flies

STERILIZING THE EGGS

Apparatus (Fig 134)—The component parts of the sterilizing apparatus are as follows —

Gallon bottle (A) containing 0 85 per cent sodium chloride solution connected with the sterilizing chamber (C)

Gallon bottle (B) containing a 10 per cent solution of formalin, tinted blue, a two holed rubber stopper into which is inserted a glass funnel filled with sterile cotton-wool and covered with gauze, and rubber and glass tubing connected with the sterilizing chamber (C)

[1] I am indebted to Professor James Ritchie, M A , D Sc , of Edinburgh, for details concerning these flies —Ed

Sterilizing chamber (C) consisting of a piece of glass tubing 6 × ¾ in.; three rubber stoppers a funnel filled with cotton wool and covered with gauze; miscellaneous pieces of glass and ¼-in rubber tubing. The chamber is closed at the top with a two-holed rubber stopper Into the stopper are inserted (1) the glass funnel and (2) glass tubing which is connected to A and B as shown. In the middle of the chamber is a rubber stopper which has been reamed out so that its walls are about 3 mm. thick A string is fastened to the stopper by means of a small strip of wood (D). The top of the stopper is covered with close meshed gauze upon which the eggs collect The bottom of C is closed with a one holed stopper through which projects a piece of glass tubing B and C are sterilized separately the latter being wrapped in paper This apparatus ensures that no air comes in contact with the fluid or the eggs without being filtered.

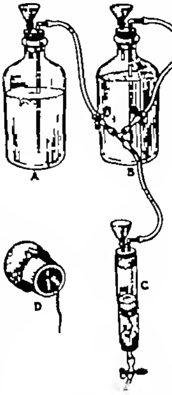

Fig 134

Apparatus for sterilizing the eggs.

Technique of sterilizing the eggs—The top stopper of C is removed and the eggs are poured in. The saline from A is allowed to run through C, and the eggs are caught in the gauze covering the middle stopper A is then turned off and the exit tube of C is closed. The formalin solution from B is then run in slowly until C is filled. The formalin solution is run out and C refilled with it several times in order to agitate the eggs. After this process has been repeated for five minutes the formalin is shut off and saline solution from A is run in once more The formalin is coloured with methylene blue so it is easily apparent when the eggs have been washed adequately After the washing process is completed, the lowest stopper in C is removed and the lip of the tube is flamed. The middle stopper is pulled down by the attached string, the lip of the tube is again flamed and the middle stopper is pulled out. The gauze with the eggs attached, is transferred aseptically with forceps to a 4-oz. specimen bottle (Fig 135).

Fig 135

A specimen bottle to which the sterile eggs in the gauze are transferred.

The entire process of sterilization is completed by one person in approximately eight minutes. The volume of eggs sterilized at one time is about 1 c.c. It has been found that a cubic centimetre contains approximately 4,000 eggs.

CULTIVATION OF STERILE MAGGOTS

The eggs are incubated at 37 C in order to permit any bacteria which may be present ample opportunity to grow Each specimen bottle contains 10 c c. of a mixture of equal parts of whole hen s egg and 0·85 per cent sodium chloride solution, which has been placed in a bath of boiling water to allow the egg mixture to coagulate The egg mixture is then broken up or the maggots will not be able to feed on it. A small piece of gauze soaked in 0 85 per cent sodium chloride solution, is placed in the specimen bottle which is closed with a perforated metal screw cap packed with cotton wool. The bottle is then autoclaved. The bottles are placed in a glass jar containing water-soaked gauze to keep the air moist

When the maggots are from 4 to 5 mm. in length they are ready for use They are tested for sterility from twenty four to thirty-six hours after hatching Several maggots are transferred to each of the following media: 1 per cent. dextrose agar 1 per cent. dextrose brain broth, and meat mash covered with vaseline for anaerobic culture The maggots are kept at room temperature and if growth is observed within forty-eight hours this particular batch is discarded. It should be noted that if a specimen bottle has an odour the batch of maggots which it contains is invariably non-sterile

MAGGOT THERAPY [1]

Confining the maggots to the wound—In the early stages of maggot therapy cages were constructed about the wound in all cases They are still useful in certain instances A maggot cage can be improvised from adhesive plaster and gauze (Fig 136) and with a little ingenuity it can be adapted for use in any type of wound

[1] Antitetanic serum must be given routine when maggot therapy is employed

R G, a boy aged 3, was admitted with a condition diagnosed as chronic osteomyelitis of the left mandible A draining sinus was present The bone did not heal after curettage About six months later another operation was performed and eight days afterwards maggots were applied, using a cage (Fig 137) The maggots were removed after three days Two weeks later the wound was completely healed The patient was ambulatory and was unaware of the type of treatment Two similar cases have since been completely cured

The application of a cage is time-consuming and, as has been stated, is usually unnecessary providing the habits of maggots are understood

The habits of maggots—The period necessary for full growth of a maggot is between forty-eight and ninety-six hours The rate of their growth within a wound depends upon the amount of necrotic tissue present and the number of maggots employed Maggots will not migrate from a wound until they are fully grown.

Maggots have no difficulty in penetrating gauze in order to reach the

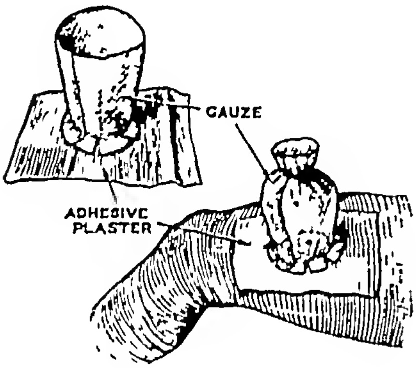

FIG 136

A cage for confining the maggots to the neighbourhood of the wound This is seldom necessary

FIG. 137

Maggot cage in use in osteomyelitis of the jaw (*Journal of Bone and Joint Surgery*)

wound In one experiment freshly hatched larvæ penetrated 5 in of dry, closely packed gauze in order to reach their food

At the end of twenty-four to forty-eight hours the activity of the maggots is maximal Usually at the end of seventy-two hours the maggots have ceased to feed and, if required, fresh maggots must be substituted

Transferring maggots to the wound—A layer of gauze is applied over the wound The maggots are removed from the specimen bottle by picking up the gauze therein with sterile forceps and wiping it around the sides of the bottle This mops up the majority of the maggots If any are left, a fresh piece of sterile gauze is placed in the bottle and the procedure repeated

The maggots are placed upon the layer of gauze covering the wound They are covered immediately by a number of layers of dry gauze These layers absorb discharge which otherwise would drown the maggots

The number of maggots applied should vary with the size of the wound and the amount of necrotic tissue therein It is essential that a large number be used A minimum is the number hatched from 1 c c of eggs, *i e*, about 4,000 maggots

Management of the maggots in the wound—The wound is dressed at the end of twenty four hours At this time many of the maggots will be found in the gauze However when they are exposed to the light they tend to burrow into the gauze toward the wound Why the maggots burrow into the gauze is obscure but it is possible that as the gauze soaks up discharge so the maggots prefer to feed there Be that as it may there is a continuous migration from the wound to the gauze

The moist gauze is removed but those layers containing maggots are replaced on the wound and covered with new layers In forty-eight hours the wound is dressed again or sooner if there is a large amount of exudate At this time the larger maggots will be in the gauze and are taken away with it Those that remain in the wound may be picked out with forceps but as a rule it is preferable to leave them *in situ* The dressing is changed at about twelve-hour intervals and on each occasion more and more of the maggots are taken away until at about sixty to seventy two hours practically all of them will have been removed

Irrigation of the wound is unnecessary and harmful Even if normal saline is employed the active principle[1] liberated by the maggots which is believed to be of considerable therapeutic value will be washed away

When removal of the necrotic material is complete maggots can still be employed Their function now is to keep the wound clean and promote healing Much fewer are required for this purpose In soft tissue infections two or three applications are sufficient for the complete removal of necrotic material In osteomyelitis many more applications are necessary

THE ROLE OF MAGGOTS IN AN INFECTED WOUND

The action of maggots is twofold —

(*a*) When used in sufficient numbers they rapidly and thoroughly remove necrotic tissue

(*b*) They stimulate the formation of granulation tissue

As has been emphasized throughout this work excision of a visibly infected wound is the quintessence of bad surgery Maggots are vouchsafed what is forbidden to the surgeon for they can remove necrotic tissue without interfering with Nature s protective barriers Furthermore maggots can crawl into every nook and cranny and accomplish what the knife can never do Maggot therapy has proved particularly efficacious in soft tissue infection with extensive laceration and a large amount of necrotic tissue Maggots do not digest dead bone but observers are unanimous that sequestration is hastened by the use of this form of therapy

CLINICAL OBSERVATIONS DURING MAGGOT THERAPY

Comparatively little discomfort is experienced by a patient undergoing maggot therapy of a wound. There may be a certain amount of irritation caused by maggots crawling over the skin in certain wounds this can be prevented in part by painting the surrounding skin with collodion As

[1] "The active principle excreted by the maggots appears to be allantoin."—Robinson

long as they have plenty of necrotic material upon which to feed, the patient is practically unaware of their presence, but discomfort is increased as the amount of necrotic tissue diminishes, for maggots irritate normal tissue The discomfort thus occasioned is controlled easily by appropriate doses of sedatives It should be noted that after the maggots have completed their work, i e, removed the necrotic material, a slight amount of bleeding occurs This is the time that the patient's discomfort reaches the maximum and morphia may be required for the relief of pain During the time that the maggots are most active the patient's temperature frequently rises 2 to 4 degrees Pitting œdema is sometimes observed around the wound during the first day or two, but it subsides on the third or fourth day

RENEWAL OF LAYING STOCK

The gauze and the maggots which have been removed from the wound are collected in a large can and covered with a cloth At the end of three or four days most of the maggots will have pupated The pupæ are shaken out of the gauze, stored in an ice-box for not longer than two weeks, or allowed to hatch, depending upon the need for additional flies Each fly is checked as to species before being used by the method described Occasionally, if the maggots removed are small, a piece of meat is placed in the can so that the maggots can complete their growth

POSSIBILITIES OF MAGGOT THERAPY ON A LARGE SCALE IN WAR WOUNDS

One technician can take care of two cages and sterilize about five batches of maggots an hour

Culturing the batches of maggots can be dispensed with as the presence of an odour is an invariable sign of contamination As regards tetanus infection, the routine administration of antitoxin and then toxoid will obviate any fears on this score Bottles of maggots can be kept on hand for at least a week at room temperature their growth being restrained by limiting the quantity of food available Since some of the mortality among the maggots is due to drying, they may be kept in a large chamber in which some water or water soaked gauze is present It is not essential to store the larvæ in an ice box, as a matter of fact, this may be somewhat detrimental to them

Stretcher-bearers and rescue parties can be trained to carry bottles The application of the maggots is, of course, quite easy, merely placing them in the wound and covering the latter with a large gauze dressing With severe hæmorrhage maggot therapy is contraindicated, as the first essential is to control bleeding The use of maggots may be likened to a first aid dressing It may well happen that with large numbers of casualties it would be impossible to handle all the wounded immediately, and the function of the maggots will be to hold the infection in check till such time as the surgeon is available

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CHAPTER XVII

METHODS OF REMOVING PROJECTILES AND KINDRED FOREIGN BODIES

PROJECTILES may be removed by immediate operation or by intervention at some later period—primary and secondary (delayed) removal

PRIMARY REMOVAL

The ideal treatment of war wounds is immediate operation to open up the track to its depth and remove all injured tissues consequently the causative agent *i e* the projectile bullet shrapnel ball or piece of shell will in the majority of cases be found and removed This is especially true of wounds of the limbs In wounds of the abdomen chest or head, the position is somewhat different Here it is not the infection that is the most important factor but rather damage to important organs viz intestines lungs brain etc Once repair of these organs has been effected as a rule no search is made for the projectile if it is not apparent at once

In wounds of the limbs when the track has been excised the projectile should be located and removed In most cases good radiographs taken in two planes at right angles to one another will be of great assistance not only in finding the projectile but also in formulating the extent of the operation

How far the operation should be extended and how much time should be spent in the search for the projectile will depend not only on the condition of the patient but on the conditions under which the operation is being performed A Odelberg came to the conclusion that it is often best to remove a foreign body by operating through sound tissue rather than through the original wound

In primary operations it is neither possible nor advisable to adopt the complicated methods of localization or procedure which may be indicated in secondary operations

SECONDARY OR DELAYED OPERATION

When for one reason or another a projectile remains in the body its removal may be indicated for various reasons —

(*a*) Its presence may prevent the wound from healing
(*b*) It may be responsible for recrudescence of inflammation
(*c*) It may be causing pain or be interfering with function
(*d*) The knowledge of its continued presence in the body may be the cause of mental or psychical symptoms

In deciding whether or not to remove a projectile the foregoing considerations must be taken into account It must not be forgotten that there is a certain amount of danger in the operation Even when it is performed long after the wound has healed soundly, the removal of the foreign body may light up sepsis sometimes even serious infection such as gas gangrene or tetanus For this reason it has been suggested that prophylactic injections should be given, particularly in the case of fragments of shells or bombs Unquestionably special precautions should be taken in the technique of the operation, for instance, the pocket in which the projectile is found and the operation wound may be smeared with B I P P and packed with impregnated gauze or drained for a few days Sulphonamide therapy has provided us with a further method of combating the danger of lighting up infection A short course of oral chemotherapy, preceding and following operation may be combined with impregnation of the surface of the wound with sulphanilamide powder If these precautions are taken, the danger of serious infection following the operation is slight When the operation is performed after a protracted interval (years) the projectile may be found surrounded by a definite capsule of condensed tissues and it may be possible to excise this capsule with advantage

In cases where a projectile has not been extracted at the primary operation and its removal is thought advisable, it is usually preferable to wait until the wound has healed soundly, for weeks or months, before attempting the operation In this way a clean operative field is obtained and there is less danger of lighting up infection

In every case, before proceeding to the operation of delayed removal of a foreign body it is necessary that the operator himself should have visualized the position of the projectile in the tissues In the majority of cases the methods employed for localizing a foreign body described in Chapter IX can be applied There are, however, a number of other procedures which the surgeon can adopt, all having their protagonists and special advantages Some of the more important of these methods will now be described

(A) **Insertion of pointer under fluoroscopic screen**—This method is suitable for foreign bodies situated deeply in the limbs or in the back

The patient, in the same position that he will occupy on the operation table, is examined in the X-ray room under the screen, and a fairly coarse syringe needle is pushed through the skin and tissues till the point of it is seen to be in contact with the foreign body (Fig 138) The patient is transported to the operating theatre Providing the hollow needle has not become displaced whilst the patient is being transported and anæsthetized, it is a simple matter to cut down alongside the needle and locate and remove the foreign body

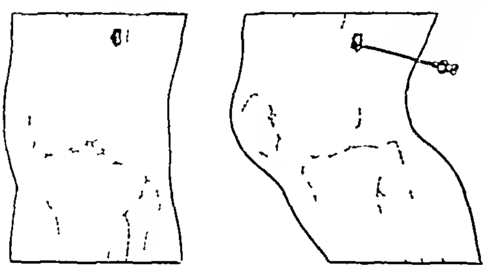

FIG 138

Anteroposterior and lateral views of foreign body in popliteal space In the lateral view the foreign body has been localized by a hollow needle, inserted under the X ray screen

In order to avoid displacement it is essential to have the patient on the stretcher in the same position all the time, while being screened, transported to the theatre and placed on the operating table If local anæsthesia can be employed, so much the better, but in this instance it should be injected before the pointer is placed in position, as otherwise the distension of the tissues may itself cause displacement The pointer should be placed in position by the operator himself Where the foreign body is situated in a hand or foot it may simplify matters to fasten the part to a wooden splint

(B) **Operation in X-ray room, partially under the screen,** is suitable for cases where the operative procedure is not of a serious or complicated nature Its only limitations are the size of the X ray room its lighting and general unsuitability for operative work The foreign body having been visualized under the screen the operation is commenced under direct vision by artificial light when the neighbourhood of the foreign body is reached the part is viewed by the screen and a blunt dissector or forceps is pushed down to the foreign body it may be possible to grasp it by a forceps and remove it directly (Fig 139) In other cases where the foreign body is situated close to important structures it may be necessary to alternate blunt exploration under the screen with careful dissection under direct vision several times before the object can be removed safely

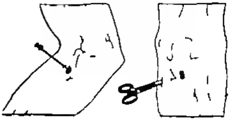

Fig 139

Foreign body in antecubital fossa.

A. In the lateral view the foreign body has been localized by a hollow needle

B In the anteroposterior view the foreign body has been seized by forceps inserted through a small incision under vision with an X ray screen.

One of the disadvantages of the method is that a considerable time must be spent at each change from direct vision to the use of the screen in order to allow the eyes to accommodate themselves to the change this difficulty can be overcome to some extent if an assistant does the screen work and keeps his eyes closed when the operator is working by direct vision in artificial light Perhaps the greatest disadvantage of the method is that the work is being undertaken largely in the dark and not in an operating theatre Special care must therefore be taken by all concerned to avoid any breach of the aseptic technique and this is not an easy matter

(C) **Operation in operating theatre under the X rays, by means of special table with box tube carrier underneath and bonnet screen worn by operator or his assistant**—Here a portable X ray generator is installed in the theatre or immediately adjacent to it and heavily insulated cables connect this to a box tube carrier moving on rails under a special operating table with a thin aluminium top To avoid having to darken the theatre the screen bonnet of Dessano (Fig 140) can be used instead of an ordinary screen The screen bonnet is worn strapped to the head and when the front of it containing the X ray screen is lifted up a dark red glass automatically closes the aperture of the eyepiece

Fig. 140

The X ray screen bonnet in use

There are two distinct methods in which this bonnet may be used —

1 The foreign body having been previously localized the operator commences the operation and when he has reached the region where the foreign body is thought to be the bonnet is placed on his head

is a certain amount of danger in the operation. Even when it is performed long after the wound has healed soundly, the removal of the foreign body may light up sepsis, sometimes even serious infection such as gas gangrene or tetanus. For this reason it has been suggested that prophylactic injections should be given, particularly in the case of fragments of shells or bombs. Unquestionably special precautions should be taken in the technique of the operation: for instance, the pocket in which the projectile is found and the operation wound may be smeared with B.I.P.P. and packed with impregnated gauze or drained for a few days. Sulphonamide therapy has provided us with a further method of combating the danger of lighting up infection. A short course of oral chemotherapy, preceding and following operation, may be combined with impregnation of the surface of the wound with sulphanilamide powder. If these precautions are taken, the danger of serious infection following the operation is slight. When the operation is performed after a protracted interval (years) the projectile may be found surrounded by a definite capsule of condensed tissues and it may be possible to excise this capsule with advantage.

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In every case, before proceeding to the operation of delayed removal of a foreign body it is necessary that the operator himself should have visualized the position of the projectile in the tissues. In the majority of cases the methods employed for localizing a foreign body described in Chapter IX can be applied. There are, however, a number of other procedures which the surgeon can adopt, all having their protagonists and special advantages. Some of the more important of these methods will now be described.

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The patient, in the same position that he will occupy on the operation table, is examined in the X-ray room under the screen, and a fairly coarse syringe needle is pushed through the skin and tissues till the point of it is seen to be in contact with the foreign body (Fig. 138). The patient is transported to the operating theatre. Providing the hollow needle has not become displaced whilst the patient is being transported and anæsthetized, it is a simple matter to cut down alongside the needle and locate and remove the foreign body.

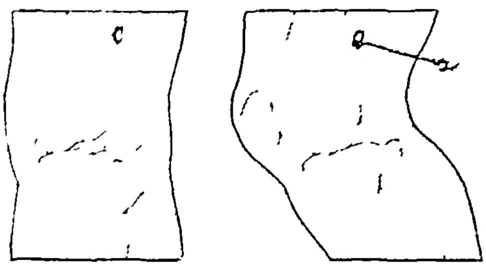

Fig. 138

Anteroposterior and lateral views of foreign body in popliteal space. In the lateral view the foreign body has been localized by a hollow needle, inserted under the X ray screen.

In order to avoid displacement it is essential to have the patient on the stretcher in the same position all the time, while being screened, transported to the theatre and placed on the operating table. If local anæsthesia can be employed, so much the better, but in this instance it should be injected magnetic bodies in its neighbourhood This vibration can be recognized through a considerable depth of tissue even when the metallic fragment is comparatively small Thus the vibration of a small shell splinter not larger than 2 mm in its greatest diameter can be recognized even though it is over an inch from the surface

This apparatus is most useful for pieces of shell as steel and iron respond powerfully to the electromagnet Bullets with their steel casing also vibrate well It is of course useless for leaden objects such as shrapnel balls or the core of machine-gun or rifle bullets

The use of this instrument is simple in the extreme The point on the skin where the maximum vibration is felt is marked and the incision is made and deepened till the piece of metal is found If this cannot be accomplished quickly the vibrator enveloped in a sterile towel is brought over the wound and the current is again switched on while a finger is kept in the wound (Fig 142) The vibrating body can then be felt distinctly and accurately located and removed It is of course necessary to remove all metallic instruments from the field of operation to prevent confusion by the vibrations imparted to them Forceps made of non magnetic alloys are of great assistance as they can be passed under guidance of the finger to the foreign body while it is still vibrating

SPECIAL INSTRUMENTS FOR EXTRACTING PROJECTILES

In addition to the forceps just described a very useful instrument for removing metallic foreign bodies capable of wide application was described by D A Willis of Chicago in 1937 To a pair of sinus forceps is attached an electric battery and a small lamp (Fig 143) The blades of the forceps are insulated from each other so that when the metallic object is grasped between the jaws of the forceps the circuit is completed and the lamp glows This is an adaptation of the idea of the telephone probe designed by A W Sheen where two insulated wires were exposed on the end of a probe Willis recommends the use of the screen with his special forceps and says the time required and the ease with which a foreign body can be removed is proportional to the accuracy of localization and the care in planning the operation

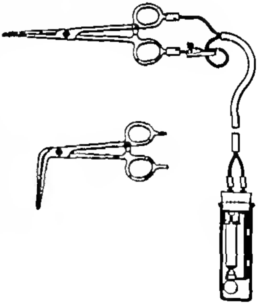

Fig 143

Willis s forceps. When a metallic body is grasped the lamp glows.

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After a few minutes to accommodate his eyes the X-rays are switched on, and with probe or blunt dissector he works through the tissues till contact is made with the foreign body which he then removes under the rays with forceps or with a guide in position he has the bonnet removed and proceeds to dissect under direct vision When there is difficulty in reaching the foreign body a certain amount of dissection can be done without removing the bonnet by virtue of the red glass which comes into place when the front of the bonnet is lifted (Fig 141) For this purpose the lighting of the theatre must be very good and it is not safe to attempt fine dissection in the neighbourhood of important structures as the view through the red glass is by no means clear

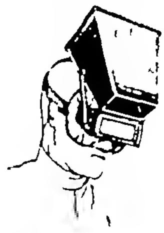

Fig 141
The X ray screen can be folded back to enable the surgeon to view the field of operation through a red glass window

2 In the second method the assistant wears the bonnet and points out the position of the foreign body in relation to the surface He continues to do so during the various stages of the operation until the foreign body is finally reached This method is better adapted to those cases in which there are several foreign bodies or in which the object lies in close relation to important structures necessitating much fine dissection The advantage of this method is especially noticeable where the foreign body is situated in bone, and by it foreign bodies may be removed from practically any situation with a minimum of injury to the tissues In all these methods where the operation is performed under the guidance of the rays whether in the theatre or in the X-ray room, it is most important that the actual time of exposure should be cut down to a minimum This is for the safety of all concerned patient operator and assistant alike

Fig 142
Bergonie's electric vibrator in use

The danger of causing X-ray burns or other injury to patient or operator has been stressed by the Faculty of Radiologists

This danger may arise either by prolonging the exposure or reducing the distance between the tube and the patient A reduction of the distance from 15 to 6 cm increases the X-ray output six times so that a medium exposure at the reduced distance may cause burns or sterility A similar warning has been sounded in America by a report from the Mayo Clinic

(D) **The electric vibrator**—Bergonié's electric vibrator is extremely useful for the removal of magnetic foreign bodies The principle on which this instrument works is that when a motor-driven current-reversing device is introduced into the circuit of an electromagnet, vibrations are set up in gross infection is present the wound is closed with deep tension sutures and the part immobilized by external splinting

In suitable cases near far figure of eight unabsorbable sutures can be placed through the skin and subcutaneous tissues These stitches are left untied and the pack is inserted as shown in Figs 144 and 145 Later

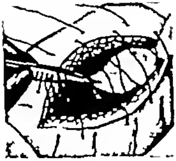

Fig 144

Pack being placed in the wound. (After Cutler and Volk)

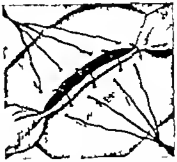

Fig. 145

Pack in place. Note the near far" figure of eight sutures.

when the pack is removed the sutures are tied This procedure causes little or no pain

CORSETTAGE

The technique of corsettage is dealt with in Chapter XV The principle is a most useful one capable of wide application and it can be employed both as a substitute for secondary suture and as a preparation for it

SECONDARY SUTURE

For a successful issue the wound must be relatively sterile and it is an advantage to carry out secondary suture as early as possible after this sterility has been achieved if possible between the fourteenth and twenty first day The reason for this specified period is that after three weeks the mat of fibrous tissue beneath the surface becomes so rigid that unfolding and approximation of the wound edges is often impracticable

Selection of cases—Unless some deleterious factor is present a septic wound of the soft parts in the course of about fourteen days has cleaned so that its surface is relatively sterile by this time sloughs have separated and the margins of granulation tissue are being levelled down by the in growing epithelial margin. On removal of the dressing the surface is covered by a bright red bed of granulations (Fig 148) and although some secretion and cellular débris is present on the surface this material is entirely innocuous indeed it may be regarded as a normal occurrence The wound is doing well and is clinically clean and fit for suture (Fig 149) If in doubt as to this a smear may be taken (see Chapter III)

Contraindications—1 The granulations are too bulky and oedematous when wiped gently with a swab they bleed at the slightest touch

2 There are adherent sloughs Even tiny sloughs showing as greyish white areas are sufficient to class the wound as unsuitable for secondary suture

CHAPTER XVIII

DELAYED PRIMARY AND SECONDARY SUTURE OF WOUNDS

WHEN a wound is left unsutured, healing by granulation will continue indefinitely or until epithelialization of the whole wound is complete Wounds are left unsutured —

1 Because they are grossly infected or considered likely to become so
2 Because suture is impossible owing to skin loss

In both classes, at the conclusion of the operation the wound will be packed As has been shown in the previous chapters, cases belonging to class 2 are eminently suitable for treatment in a plaster cast

In a number of cases belonging to class 1, when it has been ascertained that the dangers of infection have passed, the surgeon's attention will be focused upon devices for hastening closure of the wound Such measures fall into four categories —

1 Delayed primary suture
2 Corsettage
3 Secondary suture
4 Skin grafting

DELAYED PRIMARY SUTURE

The main indication for delayed primary suture is when an element of doubt exists as to the advisability of closing the wound after wound excision By delaying primary suture the grave consequences of closing a wound, which in spite of careful excision is destined to suppurate, are obviated In wounds caused by aerial bombs and high explosive shells this danger is ever present, and so it comes about that delayed primary suture is proving a measure of the first importance Little, if any, disadvantage results from leaving the skin unsutured for two or three days If the wound remains comparatively sterile, delayed primary suture is a boon, for it diminishes the period of hospitalization and reduces ultimate disability

Technique—A pack of dry, sterilized gauze or vaseline gauze is left in the wound for a few days until it becomes obvious that no severe inflammation will arise It is important that the pack should exert even and continuous pressure in every part and crevice of the wound It can be kept in place by a few skin stitches of silkworm gut this will have the added advantage of preventing unbridled retraction of the skin After an interval of two to five days the pack is removed in the operating theatre If no evidence of

Figs. 148 and 149

Before and after secondary suture

3 Sinuses or crevices are present, leading to dead bone, foreign bodies or to sloughs in the depths of the wound

4 Epithelium from the wound margins should be starting to spread over the granulations and the two tissues must be healthy and touching, any slight furrow of ulceration between the two is an absolute contraindication

Technique—Whatever application is used for the wound during the period immediately preceding secondary suture, it is essential that particular care is taken to avoid causing hæmorrhage when the application is removed The skin at the margins of the wound must be carefully cleansed Our choice is that the Carrel-Dakin method be employed for at least three days before the suture is performed As a rule a general anæsthetic is necessary After the dressing has been removed and the skin edges cleansed, the margins of the wound are approximated as far as possible In doing this, great care should be taken to minimize disturbance of the granulating surface for hæmorrhage tends to provide a nidus for residual sepsis which is always present The granulating areas must be approximated closely and no dead spaces left between them

Fig 146

When possible, tension sutures should pass beneath the granulating area

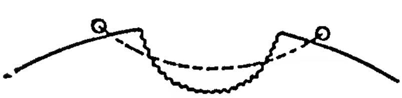

Fig 147

When it is not possible to pass the suture, as shown in Fig 146, as, for instance, when bone is at the bottom of the wound, the sutures must pass through the granulating area
(*After Morrison*)

In some cases the marginal tissues may be rolled over and approximated by deep tension mattress stitches of silkworm gut carried on a fine but long, curved, skin needle The skin is entered three-quarters of an inch from the margin and the needle passes well beneath the surface of the wound (Fig 146) before emerging on the other side at a similar distance from the margin, it then passes back again parallel to the first stitch, to emerge three-quarters of an inch from it These tension sutures may be tied over small sections of fine rubber tubing which tend to prevent them cutting into the skin At other times it is necessary to undercut the epithelial margins of the wound for an inch or so at a depth of about one-eighth of an inch from the surface along the axis of the wound, which lends itself to approximation In doing this, attention should be given to the natural lines of tension of the skin of the part, so that these are assisting and not tending to defeat the object of the surgeon in closing the wound Undercutting causes hæmorrhage, undesirable as this is, under the circumstances it is unavoidable Having freed the skin edges, the wound is approximated by silkworm gut stitches passed just outside the recently formed epithelium of the wound margins (Fig 147)

No matter which of these two types of closure is employed, it is of paramount importance to realize that the object is to obtain considerable diminution in the area of the wound, not to attain a neat approximation of the skin edges More often than not the finished operation will look far from neat, for the margins of the wound will frequently be separated by an irregular gap of granulations Nevertheless, if successful, the gap will soon be bridged Tension on stitches may be considerable, and if the near-by

CHAPTER XIX

SKIN GRAFTING IN WOUNDS INVOLVING SKIN LOSS

THE aim in all patients who have sustained losses of superficial tissue is to obtain sound healing as early as possible without contracture or other disability. It is becoming more and more evident that the finest possible dressing for a raw surface is skin. Even though the new skin is merely a temporary covering to be later replaced by another type of graft for functional or cosmetic reasons, its early successful use will avoid weeks of pain and suffering and a lifetime of disability and disfigurement from scar tissue contraction.

In the present conflict a high proportion of casualties suffer from extensive skin losses. This is the result of :—

(a) Traumatic loss of skin resulting from missiles, crashes or surgical excision of wounds.

(b) Burns—thermal, chemical or electrical.

(a) SKIN LOSS DUE TO TRAUMA

In this group the loss of skin is usually fairly limited, an exception being when there is partial or total "degloving" of a limb following a crush or run-over accident. The frequent problem presented to the surgeon is a granulating area of appreciable dimensions, and the questions to be settled are as follows :—

1. Whether the wound will become epithelialized quickly if placed under proper conditions, *e.g.* closed plaster method.
2. Whether time can be saved or contractures prevented by skin grafting.
3. Whether the granulating surface is sufficiently aseptic to graft.
4. What is the most suitable type of graft ?

Occasionally it is possible to apply a skin graft immediately to an open wound with loss of skin. This is not common in war time, for to be successful it must be done within an hour or two of the infliction of the wound and before infection can occur. If the opportunity does arise, however, it is well worth the attempt, for thereby much time will be saved.

Clinical features of a healthy granulating area.—A granulating surface showing a strong spontaneous healing tendency should be smooth, salmon pink or red, firm, flush with the general surface or slightly depressed below it, and painless to touch. Its margins should be surrounded by a bluish white film of epithelium growing centripetally and attaching itself firmly to the granulations in its progress. Daily observation of the rate of creeping epithelialization by direct measurement will after a few days give one an idea of how long the process may be expected to take and whether grafting is advisable. The type of superficial exudation is also of importance; ideally it should clot, forming an almost clear jelly after standing for a few minutes skin becomes blanched by the tension, relief may be afforded by making one or more incisions parallel to the wound beyond the mattress sutures After the operation some simple dressing, such as vaseline strips or acriflavine paste, is applied and the wound dressed and splinted so as to give it rest and light pressure When the dressing is changed one or two tension stitches which are cutting in may be divided The majority of the stitches are removed on the tenth day

RESULTS OF EXPERIENCE DURING THE 1914-18 WAR

Delayed primary suture—Sir Girling Ball described his experiences in a consecutive series of cases of delayed primary suture. There were 15 failures, 50 complete and 26 partial successes Most of the cases falling into the last category had healed completely before discharge from hospital Sir Girling came to the conclusion that many of the wounds which healed in ten days would have taken many months if allowed to granulate Even partial successes decreased the time of convalescence If the wound became infected after delayed primary suture, it could be opened at once and the patient was no worse than before

Secondary suture—John T Morrison performed secondary suture in a series of forty-one wounds He obtained eminently satisfactory results in 75 per cent of the cases As a result of his experience he claimed that, with improved technique and better selection of cases, a completely successful issue could be expected in 90 per cent He found that a bacteriological examination (Chapter III), even if only a rough-and-ready one, was a valuable guide

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Since the introduction of bacteriostatic drugs of the sulphonamide type a considerable improvement has taken place in the rapidity with which a raw surface can be conditioned After a thorough mechanical cleansing with saline the surface is powdered evenly with sulphanilamide or a mixture of three parts sulphanilamide and one part sulphathiazole A layer of tulle gras is then applied to the powdered surface followed by a moist saline dressing which is kept wet Two or three times a day the saline dressing is removed and the tulle gras floated off under warm normal saline in such a way that its removal is entirely painless and atraumatic Care is taken to see that the epithelial débris which tends to collect round the growing edge is removed for it has been found that organisms proliferate freely at this point

Bunyan Stannard bag method—Here the whole area to be cleansed and conditioned is enclosed in an oiled silk envelope which is sealed off in such a way that cross infection is impossible and the area can be irrigated two or three times a day with 5 per cent electrolytic sodium hypochlorite (Milton) Thus the surface is protected mechanically cleansed and disinfected at the same time

The preparation of a raw surface with plaster—This is not to be recommended. While the closed plaster method is ideal for the florid growth of granulating tissue epithelium grows poorly under such circumstances The macerating effect of pus has a retarding effect on the growing edge and the granulations themselves are too unstable without further treatment for grafting

While an accurate knowledge of the bacterial flora is of considerable value a bacterial count has been found in practice to be misleading Only clinical experience founded upon the appearance of the raw surface and the character of the discharge can determine the correct time to apply skin grafts In general an average infected raw surface can be prepared for grafting in seven to ten days the last three or four days being devoted to saline packs alone

When deep structures are involved—Sepsis in deep structures is the commonest cause of persistent infection in granulating areas The cause must be removed before a serious attempt is made to render the granulating surface healthy In cases of loss of the scalp with an area of sequestration of the skull the latter is best left alone to separate spontaneously In the meantime surrounding raw surfaces may be grafted up to the edges of the sequestrum As soon as the sequestrum separates the granulations beneath can be prepared for final skin grafting

When important viable structures lie in the wound *e g* tendons of the back of the hand the advisability of employing pedicle flaps rather than free grafts must be considered in order to increase a failing blood supply to those structures

(*b*) RAW SURFACES RESULTING FROM BURNS

Third-degree burns involving the entire thickness of the skin are the most common and important source of raw surfaces both in peace and war Raw surfaces from burns differ from traumatic skin loss both in extent and in behaviour Failure to heal rapidly and soundly is expressed by deficient or absent epithelialization at the wound edges or by piling up of epithelium

The indications for grafting a healthy granulating area—*A raw surface* presenting the features just described will often heal rapidly and soundly, and the decision to graft it will depend on its size, shape and location The size of the area is entirely a relative matter, depending on its location For example, a skin loss of a few centimetres on the face or hands may be eventually far more disastrous from the standpoint of contractures than a very large loss on the body or limbs, and will therefore require early skin grafting On the body any raw surface larger than the palm of the hand should be grafted, particularly if it is more or less circular as opposed to a long narrow defect which will heal rapidly from the sides Raw surfaces over joints and defects encircling the limbs should be grafted to protect weight-bearing areas and to prevent constricting bands

When presented with a healthy granulating area, after taking into consideration the foregoing, the main question to be decided is whether time will be saved by applying skin grafts

Clinical features of an unhealthy granulating area—An infected raw surface presents painful, soft nodular, exuberant greyish-yellow granulations exuding frank pus, with little or no epithelial response at the edges Considerable incrustation with dried pus keeps the surface irritated and prevents proper drainage The infecting organisms are usually *Staphylococcus aureus* and *albus*, mixed with various saprophytes and occasionally the streptococcus or *B pyocyaneus* The last named will produce green pus and is easily recognized One must realize that infection is not purely a surface affair but extends down through the thickness of the granulations Heaped up exuberant granulations are often good evidence of retained sequestra or underlying sepsis, the cause of which should be sought

Conditioning an unhealthy granulating surface—The control of infection and the preparation of the raw surface for grafting are matters for skilful and devoted nursing Efficient treatment is at the same time the best stimulus to epithelialization There is no easy road by antiseptics or dressings occasionally applied Whatever the actual method, it is certain that strict surgical cleanliness is essential, provided that the epithelializing surface is not damaged in any way, either by strong antiseptics or by trauma Thus a concentrated course of alternating normal saline and one-quarter to one-half strength eusol packs is a most satisfactory method for disinfecting and 'conditioning" a granulating surface These packs should be applied two-hourly, covered with oiled silk and bandaged firmly to the raw surface so that the granulations are actually under pressure A saline dressing is left on during sleep, but is moistened by the nurse from time to time with an undine or bottle of sterile saline The packs are changed frequently to prevent the granulations drying, otherwise pain and bleeding are caused on removal Under this treatment rapid reduction in the exuberance of the granulations occurs, discharge lessens and pain decreases The disappearance of pain is an excellent indication that the infection has been controlled It has been pointed out already that healthy granulations are painless when touched When this stage has been reached eusol is discontinued and saline packs alone are used, rather less frequently Eventually a dressing of tulle gras is applied to cover and protect the surface At the slightest sign of relapse the saline-eusol packs are resumed

TANNIC ACID TREATMENT HAS NOT BEEN USED—When there is no doubt about the third-degree nature of a burn it should be treated immediately with saline packs followed by gentian violet or triple dye As previously stated in my opinion tannic acid or any other heavy coagulant should be avoided in third-degree burns and every effort must be made to prevent infection

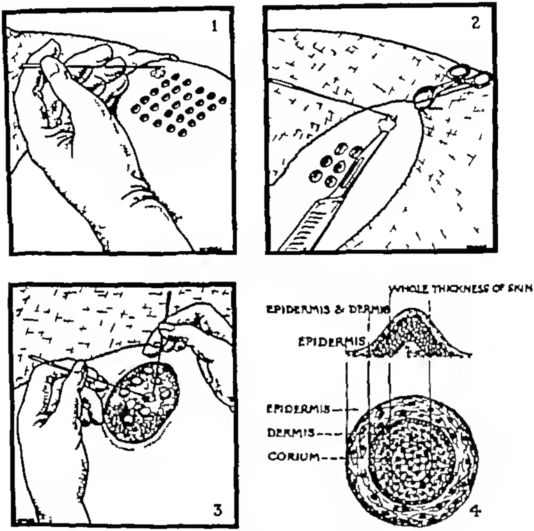

FIG. 150

1 Small deep graft elevated with needle.
2, Grafts shaved off flush with the surface of the skin.
3, Grafts applied to raw surface
4 Diagrammatic representation of the constitution of a small deep graft

FREE SKIN GRAFTS SUITABLE FOR WAR SURGERY

Under war conditions the most generally useful free grafts are —

(a) Small deep grafts (Staige Davis)
(b) Thin razor grafts—epidermal (Ollier Thiersch)
(c) Thick razor grafts—dermo-epidermal intermediate or split skin grafts

By a judicious use of one of these almost any loss of skin can be replaced satisfactorily which fails to adhere to the granulating base The base itself becomes easily infected and can be sterilized only with difficulty Healing, if it occurs, is achieved painfully and slowly Scar epithelium is either so thin that it breaks down under the slightest trauma or so thick as to form unstable keloidal tissue

Should a third-degree burn be of such localized dimensions that it can be excised and grafted immediately a long period of disability can be avoided In this way a burn loss is transformed by excision into a traumatic loss with consequent improvement in the prognosis

The reasons for failure of epithelial response in third-degree burns are threefold —

1 Local sepsis and the extent of skin loss
2 Poor vascularity of underlying partially burnt tissue
3 The depressed general condition of the patient

In preparing burnt raw surfaces all three factors must be taken into account and dealt with

Preparing a third-degree burnt area for skin grafting—TANNIC ACID TREATMENT HAS BEEN USED—The modern treatment of burns by tannic acid has proved adequate except for those of the third degree which have become infected In these cases I strongly deprecate its use The sooner the tan is removed the better, for the macerating effect of pus in the closed treatment of granulating surfaces inhibits the epithelial response and may even cause second-degree areas to become third degree The retention of tan in the presence of sepsis has been advocated by some on the grounds that (*a*) the patient is more comfortable with tan undisturbed, and (*b*) healing occurs beneath the tan

There is no doubt about the former but experience would show that apparent third-degree burns which heal in the presence of sepsis beneath tan are in reality only partial skin losses If the whole thickness of the skin is destroyed, epithelialization is delayed by the closed method Only if it is necessary to preserve the morale of a patient who would be unable to withstand energetic local treatment should one persevere with this method

After removal of the tan a course of saline or saline and eusol packs is employed if the area is reasonably small When the area is large the constant temperature saline bath is prescribed A special bath has been invented for this purpose but an ordinary bath can be substituted The patient is immersed in normal saline at blood heat for one to two hours each morning and afternoon Head and face burns are irrigated and the joints of the limbs can be moved painlessly in the saline By the use of saline baths many contractures are avoided Between baths the patient lies naked on a sterile sheet in a tented bed, the burnt surfaces being covered with saline packs, tulle gras or vaseline gauze Radiant heat lamps are used to keep the patient warm As far as possible raw surfaces are not allowed to dry, particularly after removal from the saline If the bath produces pain it is probable that the salt solution is not of physiological strength and this must be carefully controlled with an indicator Under this treatment it is surprising how quickly a clean surface is obtained and how rapidly epithelialization from the edges or from stray islands in the granulations takes place of grafts is covered with tulle gras which in turn is covered by layers of gauze wrung out in paraffin and flavine A sterilized sea sponge of the type known as elephant's ear follows and pressure is exerted on the dressing by means of a crêpe bandage applied firmly If the area to be grafted is large much time can be saved by team work one operator taking the grafts

Fig 153

A, Large thick razor graft cut from outer side of child's thigh with simple knife-and board technique.
B Removing the graft. Its opacity indicates its thick character

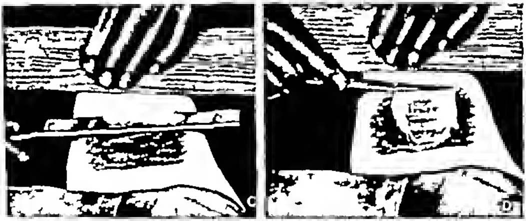

Fig. 154

C, Thin razor graft cut from inside of right arm, using simple knife-and board technique.
D Dividing the graft Note the thinness of the graft.

and another applying them Two or three needles loaded with grafts are passed in succession between them The area from which the grafts are taken should be inconspicuous for unsightly scarring may result

The dressings are removed in a week, when each island of skin will have taken (Fig 151) Saline dressings are continued if mild infection is present, otherwise a tulle gras dressing is applied By coalescence the epithelial islands make a continuous, uneven but stable covering (Fig 152) If the islands are cut too small or are placed too far apart the granulations between

Choice of grafting method will depend upon whether immediate or delayed grafting is decided upon, the site and extent of the raw surface and the general condition of the patient.

Small deep grafts (syn. pinch grafts, Staige-Davis grafts)—Here small cones of skin removed under local anæsthesia are applied directly to clean granulations If necessary this can be done as a ward procedure Pinch grafts have a distinct but limited field of usefulness and are suitable for extensive skin losses on the trunk or legs where large razor grafts from other sites cannot be obtained without difficulty They are also indicated where it is essential to spare the patient any further shock Pinch grafts should not be used on the face or hands, for the cosmetic result is not pleasing A distinct disadvantage is that the method is a comparatively slow one

FIG 151

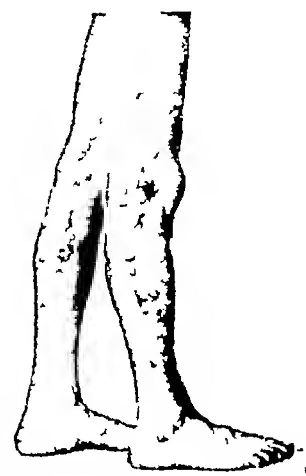

FIG 152

FIG 151—Small deep grafts applied These are beginning to spread and coalesce
FIG 152—Complete healing with full movement The cosmetic result is poor, but the graft is stable and efficient

Finally, the functional result may be poor, for slow epithelialization favours the formation of scar tissue Wherewithal it is obvious that, except in unusual cases, pinch grafts are decidedly a second choice

TECHNIQUE—Choosing a piece of skin near the area to be grafted, a straight needle is engaged in the epithelial layer, which is lifted into a small cone (Fig 150 (1)) With a sharp scalpel the base of the cone is cut through flush with the surrounding skin in such a way that from apex to base the cone contains all layers of the skin (Fig 150 (2)), the mid-periphery consists of dermo-epidermis and the periphery is epithelium alone (Fig 150 (4)) In size the graft should be 2 to 6 mm in diameter It is removed forthwith on the needle to the granulating area, which has been prepared with saline but not scraped or shaved The cone of skin is then placed carefully against the granulations so that its epithelial edges are flatly spread on the surface Further grafts are applied in the same way in rows 1 cm apart (Fig 150 (3)) As the work proceeds a hair drier is used to dry the surface and coagulate the serum which exudes from the granulations Finally, the entire crop

There are three practical methods by which thin or thick razor grafts may be cut —

(a) Free hand with the Blair graft knife and sucker or board (Fig 135 (1 and 2))
(b) Partly mechanical with the Humby roller knife and board (Fig 135 (3))
(c) Almost entirely mechanically by the Padgett dermatome

The free-hand method is used by most experienced plastic surgeons for it is quick accurate and requires nothing beyond experience a sharp knife and the board or Blair sucker to flatten the skin in front of the advancing blade A thin razor graft is cut as thinly as possible without perforating the surface epithelium a thick razor graft as thickly as possible without penetrating into the subcutaneous fat

It is as difficult to describe the technique of free hand graft cutting as it is to teach golf by correspondence but the following points may prove helpful —

(a) See that the knife is razor sharp with a biting edge
(b) Use for preference the inner side of the left leg the outer side of the right leg or the inner side of either arm (for hairless grafts) In this way the knife can cut upwards and the skin falls evenly over it without fouling the edge
(c) Avoid an uneven surface or one which cannot be smoothed with the board The projection of the adductor longus on the thigh or the groove between the deltoid and triceps on the inner side of the arm can make an even graft impossible Complete muscular relaxation will overcome this
(d) Stand over the leg or arm in an easy position well braced and balanced on both feet Keep the knife hand wrist and forearm stiff and in the same axis and control the sawing action from the elbow which is lightly pressed against the side The see saw movement which inevitably results in a perforated graft is thus prevented The whole body should move along with the knife as it progresses Do not force the knife to cut the skin but make the sawing motion even and with the lightest pressure If the knife is sharp the skin will flow over its back edge without difficulty
(e) Judge the thickness of the graft by the colour of the cutting edge of the knife through the skin With a thin razor graft the edge is blue-grey and can be distinctly seen As the graft is cut more and more thickly the tint changes to a yellow white and finally the graft becomes opaque and the edge disappears from view When this happens it is well to beware of deep perforation into the subcutaneous tissue
(f) If the full thickness of the skin is perforated it is better to stop and be satisfied with what has been taken or re lay the skin and start again The damage done by attempting to persevere with a badly perforated graft may become worse than the original lesion
(g) Resharpen the knife after every operation Not even an expert can cut a graft with a blunt knife

tend to become hypertrophic before coalescence can occur In this way healing is delayed

Razor grafts—*The thick razor graft* (Fig 153, A and B) is the most generally useful of all free grafts for the covering of raw surface It consists of epidermis, dermis and small amounts of corium Under war conditions this method would be used in probably 80 per cent of cases For immediate use, for delayed covering of granulating wounds, or for the relief of late contractures, it is the quickest and surest way to replace lost skin

Thin razor grafts (syn Ollier-Thiersch grafts, epidermal grafts) (Fig 154, C and D) are used chiefly for lining cavities such as the eye-socket, the nasal

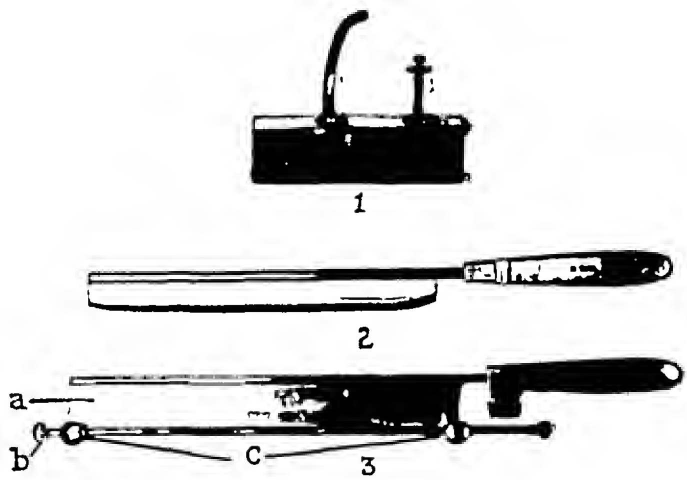

Fig 155

1, The Blair-Brown suction box, producing a smooth surface for the Blair Knife A negative pressure is obtained inside the box by means of the ordinary theatre sucker attached to the curved tube at the top
2, Note that the knife has a long safety razor pattern blade set into a thin rigid back It is light and well balanced
3, Humby roller knife —
a, Blade *b*, Sliding milled bar *c*, Adjusting screws
The bar *b* rolls forward over the skin The knife *a*, adjustable at *cc*, oscillates on the roller and cuts a graft of measurable thickness

cavities, etc , or for covering clean raw surfaces where the granulations themselves are not disturbed On the whole they are not often used in the treatment of raw surfaces of traumatic origin

There are two modifications of the method —

1 Cut into tiny pieces and applied discretely over the surface, the razor grafts are known as Reverdin grafts
2 These pieces may be buried beneath the granulations if sepsis prevents surface use Such variations are unnecessary and should find little favour

Technique—The accurate cutting of razor grafts is a matter of great importance and the acquisition of the requisite skill is entirely a matter of practice and a sharp knife The latter is absolutely essential

There are three practical methods by which thin or thick razor grafts may be cut —

(a) Free hand with the Blair graft knife and sucker or board (Fig 135 (1 and 2))
(b) Partly mechanical with the Humby roller knife and board (Fig 135 (3))
(c) Almost entirely mechanically by the Padgett dermatome

The free-hand method is used by most experienced plastic surgeons for it is quick accurate and requires nothing beyond experience a sharp knife and the board or Blair sucker to flatten the skin in front of the advancing blade A thin razor graft is cut as thinly as possible without perforating the surface epithelium a thick razor graft as thickly as possible without penetrating into the subcutaneous fat

It is as difficult to describe the technique of free-hand graft cutting as it is to teach golf by correspondence but the following points may prove helpful —

(a) See that the knife is razor sharp with a biting edge
(b) Use for preference the inner side of the left leg the outer side of the right leg or the inner side of either arm (for hairless grafts) In this way the knife can cut upwards and the skin falls evenly over it without fouling the edge
(c) Avoid an uneven surface or one which cannot be smoothed with the board The projection of the adductor longus on the thigh or the groove between the deltoid and triceps on the inner side of the arm can make an even graft impossible Complete muscular relaxation will overcome this
(d) Stand over the leg or arm in an easy position well braced and balanced on both feet Keep the knife hand wrist and forearm stiff and in the same axis and control the sawing action from the elbow which is lightly pressed against the side The see saw movement which inevitably results in a perforated graft is thus prevented The whole body should move along with the knife as it progresses Do not force the knife to cut the skin but make the sawing motion even and with the lightest pressure If the knife is sharp the skin will flow over its back edge without difficulty
(e) Judge the thickness of the graft by the colour of the cutting edge of the knife through the skin With a thin razor graft the edge is blue-grey and can be distinctly seen As the graft is cut more and more thickly the tint changes to a yellow white and finally the graft becomes opaque and the edge disappears from view When this happens it is well to beware of deep perforation into the subcutaneous tissue
(f) If the full thickness of the skin is perforated it is better to stop and be satisfied with what has been taken, or re lay the skin and start again The damage done by attempting to persevere with a badly perforated graft may become worse than the original lesion
(g) Resharpen the knife after every operation Not even an expert can cut a graft with a blunt knife

The Humby knife resembles a safety razor in that the edge is guarded by an adjustable milled bar against which it works and which prevents too deep a bite of the skin being taken Up to a point the thickness of the graft can be estimated by the distance of the edge from the protecting bar, this being adjustable It is an instrument to be recommended for those who cut grafts occasionally

A

B

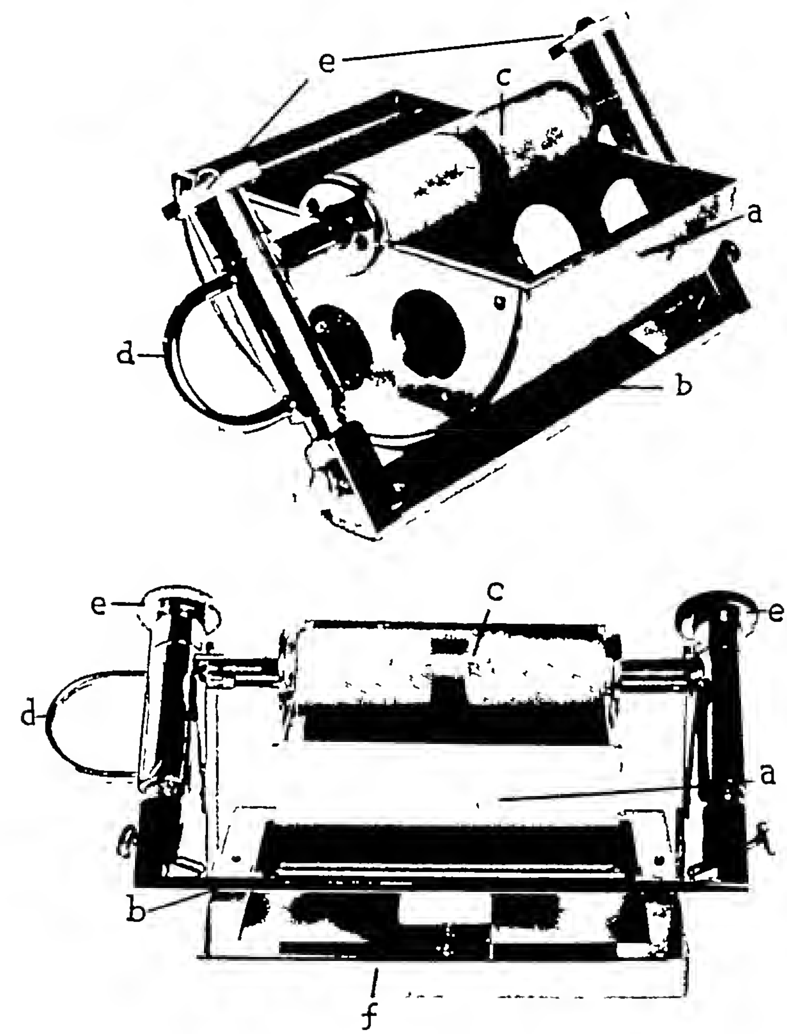

Fig 156

A, Padgett dermatome (slightly modified by Gillies), side view
B, Front view of the instrument on its stand

The smooth surface of the rotating drum (*a*) is painted with adhesive The knife (*b*) works on its axis through the drum handle (*c*) which is adjusted by the screws (*ee*) The left hand grasps the handle (*c*) and rolls the drum slowly over the skin At the same time the right hand works the knife to and fro at (*d*), and the graft is cut and remains stuck to the surface of the drum A graft can be cut of measured thickness and of any size according to the amount of adhesive used on the drum

The Padgett dermatome (Fig 156, A and B) is a more elaborate instrument with which grafts of known extent and thickness can be cut with considerable accuracy It consists of a half-circle drum with a central handle and an adjustable knife set against the periphery of the drum By painting the drum and the skin with adhesive and rolling the instrument over the sticky skin a graft can be planed off of measured size and thickness Its particular advantage lies in the fact that grafts can be taken with ease from the abdomen or back where the legs or arms cannot be used

With this dermatome the graft is removed more uniformly than by the free hand method In using this instrument a certain amount of skill is required, particularly as regards the co-ordination of the left hand which rolls the drum over the skin and the right hand, which operates the blade

THE PREPARATION OF THE GRANULATIONS AND THE APPLICATION OF THE GRAFTS

The granulating surface is washed gently with normal saline and the surrounding skin prepared with ether and spirit The granulations are then either scraped off until the deep fibrous layer is reached or excised *in toto*

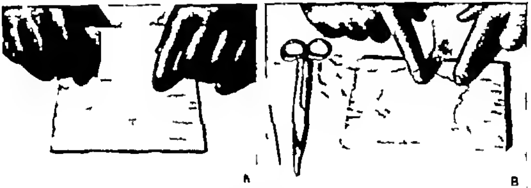

FIG 157

A Tulle gras with underlying pattern.
B Graft spread raw surface upwards on the tulle gras. It adheres to the greasy surface.

down to healthy tissues As a rule simple scraping is sufficient for excision means a much bigger defect to graft as the edges fall apart All bleeding is arrested by pressure hot packs or adrenalin 1 1 000 applications The grafts are then spread on tulle gras raw surface outwards (Fig 157 A and B) and in the case of large areas with several grafts the tulle gras squares are covered with skin and overlapped together to make one large piece A continuous graft 6 x 12 in may be constructed in this way It is then applied to the raw surface and fixed down with a few sutures round the edges In special areas such as the hands fingers and face the graft may be more accurately sutured into place and pressed home with stent (dental wax) Gauze or wool wrung out in paraffin and flavine is then applied a sponge follows and pressure is obtained by a crêpe bandage In difficult sites such as the anterior surface of the neck or the eyelids more efficient pressure tension and immobilization are obtained by sewing the graft into place with peripheral interrupted sutures one end of each being left long These long ends to the number of thirty to fifty are then tied over a sea sponge or a stent mould which is thus compressed unmovably against the graft

POST-OPERATIVE TREATMENT

At the end of seven days the dressings are removed, when it will be found that most if not all the graft has taken. Loss of the graft will usually be indicated within three days by increasing discharge and the foul penetrating smell of decomposing skin. This is an indication for removal of the dressings and resumption of disinfection.

A 100 per cent. successful graft is treated with a saline dressing for a few hours and then covered with tulle gras for two to three days. As soon as it has consolidated, light massage should be commenced. If there are minor losses of skin, saline and eusol packs may be used or gentian violet or triple dye painted on the raw spots. Aqueous mercurochrome, 20 per cent., has been found particularly useful for this purpose.

Complete failure of the graft does not imply that further attempts should be abandoned. On the contrary, the bacteriology of the discharge is investigated, active disinfection undertaken and preparations made for another graft as soon as the surface is suitable for its reception. Frequently the poor general condition of the patient is at fault and blood transfusions may be necessary. Ten to fourteen days' change at a convalescent home before regrafting is often of great benefit.

* * * * * * * *

It is reiterated that the day has passed when healing of extensive raw surfaces by scar tissue should be countenanced. Such treatment is almost criminal.

SECTION V

WOUNDS OF BLOOD VESSELS

CHAPTER XX

TOURNIQUETS AND THEIR APPLICATION

"TOURNIQUET—A surgical instrument consisting essentially of a bandage a pad and a screw for stopping or checking by compression the flow of blood through an artery; also a bandage tightened by twisting a rigid bar put through it."—*Shorter Oxford Dictionary*

THIS able description should be supplemented A tourniquet is a gross form of ligature which is applied to a limb in order to prevent bleeding which cannot be stemmed by other available means It should be comprehended that this description limits the application of a tourniquet to cases of *arterial* bleeding

The indiscriminate use of tourniquets caused much damage in the 1914 18 war Infection massive gangrene pain ischæmia and gas gangrene have all been attributed to the misuse of the tourniquet There is general agreement that the tourniquet in the hands of the first-aid worker is more a source of danger than an asset Ball and Qvist found that in almost every instance tourniquets are badly applied resulting in a steady ooze of blood Such reports can be obtained on every hand and it would appear that the time has been reached when the tourniquet should be removed from first-aid equipment and the first-aid worker taught to apply a dressing and a firm bandage and to elevate the limb

INDICATIONS FOR THE USE OF A TOURNIQUET

1 **Primary arterial hæmorrhage,** which cannot be controlled by the application of a firm pad and bandage to the wound or digital pressure over the main artery In this case the tourniquet is the temporary substitute for urgent operative treatment which is to be performed at the earliest possible moment

2 **Reactionary and secondary hæmorrhage**—After an amputation a tourniquet should be at hand (usually tied to the bed rail) ready for immediate application In infected wounds and amputation stumps when secondary hæmorrhage is threatened a tourniquet should be in position on the limb untightened ready for instant fixation if profuse hæmorrhage occurs

3 **To render a field of operation bloodless**—Well known examples are for amputations and for operations on joints

TYPES OF TOURNIQUETS AND METHODS OF APPLICATION

There are a host of varieties of tourniquets Some special forms are designed for specific purposes during operations *e.g* the tourniquet to control the hilar vessels during pulmonary lobectomy and the great arteries during pulmonary embolectomy. It is not proposed to deal here with these special types

Usually when the decision to apply a tourniquet has been taken it should be applied quickly and with the minimum disturbance to an injured limb In other circumstances, *e g*, in the operation theatre, where urgency is not a factor to be considered, the limb is emptied of excess blood by elevation prior to the application of the apparatus

As a general rule a tourniquet should not be applied directly to the skin, there should be an intervening layer of cloth or wool This is to prevent injury to the skin which is very prone to occur with Samway's and most of the improvised types In cases of urgency the tourniquet may be applied over ordinary clothing and even over thick flying kit, although in this instance it is more difficult to tighten effectively, if this practice is observed there is less disturbance and exposure of the patient and less time wasted

The tourniquet is laid around the limb at a convenient level proximal to the bleeding area and tightened firmly The exact procedure varies with the type of instrument used

Improvised tourniquets—Any material which is pliable and strong may be used as an improvised tourniquet Strong bandages, folded handkerchiefs, triangular bandages neckties or pieces of rubber tubing are most suitable A rigid bar, some four inches long, is also required and may be provided from any handy sticks of wood or rods of metal

The selected material should be folded into a narrow band in order to increase its strength, and tied loosely around the limb above (proximal to) the wound A reef knot is always to be employed in order to obtain security The rigid rod is now put underneath the loose tourniquet, between it and the limb or clothing, and twisted in order to tighten the band This method is known as the "Spanish windlass" (Fig 158) and provides powerful constriction with the minimum effort on the part of the operator The rod should lie to one side of the knot when introduced underneath the band, so that when the tourniquet is tightened the loose ends from the knot can be tied over the long end of the rod in order to render it secure Otherwise it will tend to untwist

Fig 158
The Spanish windlass

During the twisting the rod should be lifted away from the skin or clothing in such a way that these structures do not become involved in the twist It is very painful if skin is so included

Samway's tourniquet—This consists of a stout rubber tube some two feet long, into one end of which there is fixed a metal "anchor" (Fig 159) Callander's modification provides a handle to this anchor (Figs 160 and 161) This greatly enhances the ease of application Samway's tourniquet should always be applied over some protective layer of cloth—a folded handkerchief will suffice—in order to protect the skin from injury The anchor is held in one

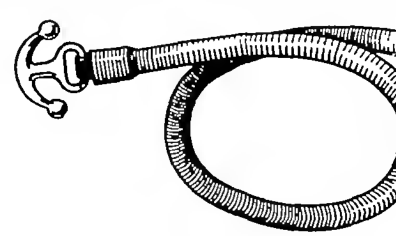

Fig 159
Samway's tourniquet

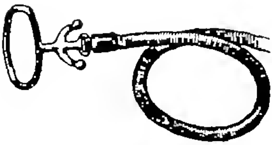

Fig 160—Callander's adaptation of Samway's tourniquet

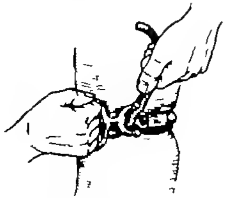

Fig 161—Showing the method of securing the tubing in the anchor

hand whilst the tube is stretched and applied around the limb with the other Usually two turns are taken around the limb and the tubing is then secured to the anchor This is done by passing the stretched tube around the shank of the anchor underneath the flukes on each side which are so designed that they will retain the tension of the tourniquet when the free end is released To remove the tourniquet it is necessary to stretch the loose end of the tubing before it can be freed from the anchor A considerable amount of strength is required both to apply and fix this tourniquet and to release it

Milroy Paul's tourniquet can be recommended because ordinary rubber tubing only is required The instrument consists essentially of a metal mount (Fig 162) for fixing the ends of the rubber tubing which are anchored in the two slots The great advantage of this tourniquet is that rubber which is so perishable especially in hot climates can be renewed at will

Fig 163
Milroy Paul's tourniquet.

Esmarch's bandage (Fig 163)—This is a rubber bandage from 2½ to 4 in in width and either 3 or 6 ft long To one end there is attached a fabric strip which is provided with two tapes for fixation after application Other types are simple rubber bandages without this fabric end

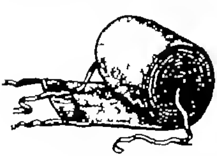

Fig 163
Esmarch's bandage

The Esmarch bandage is applied exactly as an ordinary roller bandage except that it is stretched during application and each turn of the bandage is laid over the previous layer As a result there will be several layers of the bandage in the same plane after application is completed around the limb It has to be remembered that each layer or turn will be exerting pressure on the limb and that the total effect will be the cumulated constriction of each turn Unless this is borne in mind, very great pressure may be obtained with only a moderate pull as each turn of the bandage is applied The bandage is secured in position either by tying the tapes tightly round the limb over the tourniquet or by tucking the free end under the last layer of the applied bandage (Fig 164)

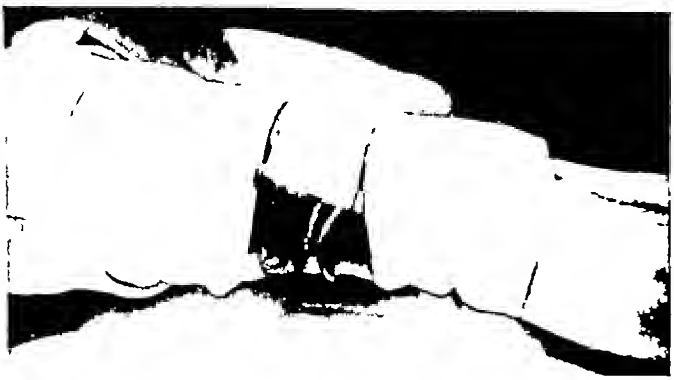

Fig 164
Esmarch's bandage applied to the thigh, showing method of tucking in the loose end for security

This tourniquet should be sterilized by boiling, and may be applied, if desired, without underlying protection It is generally used during operations on the lower limb For use in emergency Esmarch's bandage has the disadvantages that the roll may slip from the hands of the operator during application, and it causes considerable disturbance to the limb during application and removal

Pneumatic tourniquet—This instrument comprises a rubber bag which is applied to the limb and covered by an unyielding cloth bandage The bag is inflated with air by means of a bellows (Fig 165) The cuff of a sphygmomanometer is a pneumatic tourniquet, and this instrument may frequently be used with advantage in place of the simple bag, because the manometer indicates the pressure which is being employed A pressure of 200 mm of mercury is an average which will ensure obliteration of the arteries without damaging the soft tissues of the limb This apparatus can be used with advantage during operations upon the arm on account of the gentle distributed pressure which it applies This is of the greatest importance in the upper arm, where the nerves are particularly liable to injury by tourniquet pressure It is easy to apply, and is deflated by unscrewing a valve located on the bellows Mr Grant Waugh, in Chapter XXVI, extols the pneumatic tourniquet for use in cases of secondary hæmorrhage

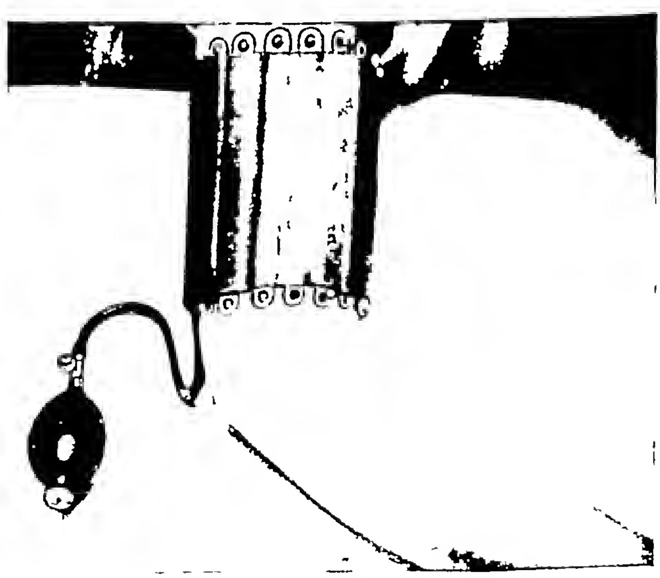

Fig 165
The pneumatic tourniquet applied to arm

St John Ambulance tourniquet consists of a web band 2 in wide and about 2 ft long with a buckle at one end. Near the buckle there is a pad on the inner side of the webbing and a loop of strong tape is fixed to the outer side of the webbing in this situation (Fig 166) The loop is 4 or 5 in

Fig 166
The St John Ambulance tourniquet.

Fig 167

Fig 168

Method of applying the St John Ambulance tourniquet.

long and is attached in such a way that when the main tourniquet is held taut it is just slack on the surface of the webbing (Fig 167) This loop is provided for the final tightening by the Spanish windlass method and it has attached to it a wooden rod with which it can be twisted (Fig 168) Through this rod which is hollow passes a string for fixation. The buckle has an extra loop to which the string is tied after the tourniquet is fully applied

The tourniquet is applied by passing the web band around the limb and tightening with the buckle after the pad has been located in position over the line of the main artery Final pressure is then obtained by twisting the wooden rod and the loop to which it is attached thereby pulling on the webbing to either side of the pad The webbing is constricted and the pad is at the same time pressed into the limb to bring particular pressure to bear upon the main vessel

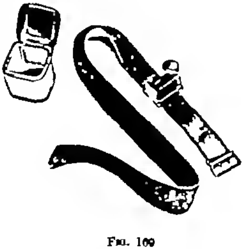

Fig. 169
Singer's tourniquet, with case.

This tourniquet is designed for the use of First Aid personnel and is particularly useful for this type of work It is simple compact and powerful Reliance is not placed solely on the location of the pad which may be ignored if there is any difficulty in determining the position of the artery The tourniquet only requires to be more tightly applied in order to control the hæmorrhage in these circumstances

Singer's tourniquet (Fig 169) is a web band 1¼ in wide and 18 in long provided at one end with a buckle The band passes through a light frame which contains a slotted rod through which the webbing threads This rod may be rotated within the frame by turning a milled knob to which it is geared by a worm drive

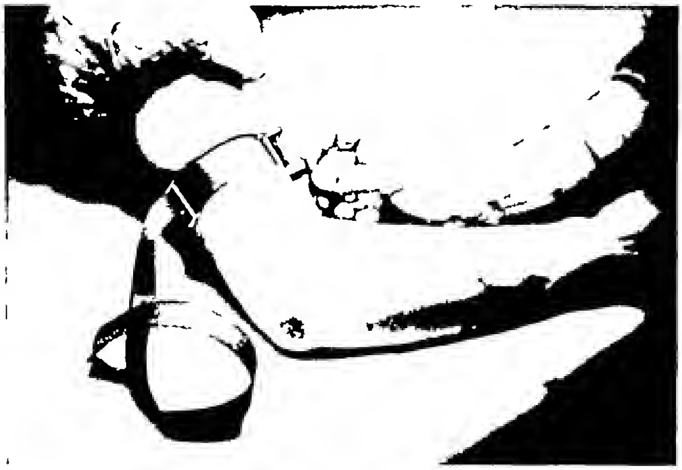

Fig 170
Singer's tourniquet in use

The band is buckled firmly in position round the limb Final tension is provided by turning the milled knob on the frame (Fig 170), whereby the rod is rotated and the webbing is rolled upon itself Considerable constriction of the limb can be obtained without difficulty or disturbance, but it is not liable to place excessive tension upon the band

The Royal Air Force has adopted this model for use in some of its First Aid outfits because of its efficiency and simplicity It weighs only 2¼ oz complete with a case, and when packed it measures 2 in square by 2¼ in high (see Fig 169)

The L.P.L tourniquet is extremely easy to apply (Fig 171) and release By pulling on the stout rubber cord the tourniquet automatically tightens Its release is effected by approximation of the finger grips, thereby releasing the spring holding the cord As shown in Fig 172, it is possible for the tourniquet to be applied by the patient himself

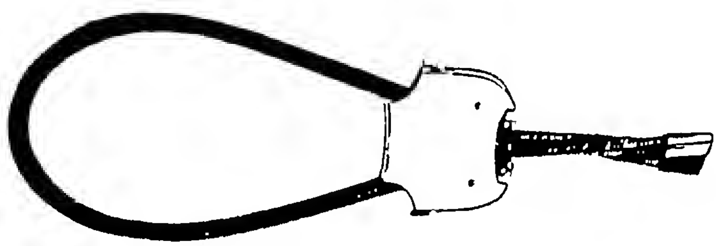

Fig 171
The L P L tourniquet

Fig 172
The L P L tourniquet applied to arm.

Screw tourniquet—The older type which consisted of a band with a frame through which there passed a screw supporting a pad, requires only passing mention here It pulled the web band away from the limb when the screw was tightened, and reliance was placed upon the pad being located effectively over the main artery It has been superseded by its modern counterparts

TOURNIQUETS USED BY THE ROYAL AIR FORCE

1. *St John Ambulance tourniquet* is provided for the use of non medical personnel in aircraft because of its ease of application and small bulk. Preliminary instruction is given to personnel who may have occasion to make use of this appliance Little difficulty is experienced in training airmen in the simple principles governing the application of this tourniquet.

2. *Singer's tourniquets* are supplied in some of the First Aid outfits both in aircraft and with the ground personnel.

3. *Samway's tourniquets* are provided for use by Medical Officers at Sick Quarters, where they sometimes prefer this type

All the types mentioned are available for use in the Royal Air Force General Hospitals It is the practice of the authors to resort in general to the use of the Esmarch's bandage as a tourniquet for the lower extremity and the pneumatic tourniquet is always used when available on the upper limb. For emergency use we prefer St John and Singer's tourniquets as they are simple and quick in application.

PRECAUTIONS AND DANGERS IN THE USE OF TOURNIQUETS

1 **Effective labelling of cases**—It is most important that each patient on whom a tourniquet is applied should be clearly and obviously marked in order to avoid any possibility of this fact being overlooked even amongst numerous casualties A large T marked on the patient's forehead together with a note of the time of application preferably in the twenty four hour system constitutes a simple and effective method

2 **Inadequate pressure**—By compressing veins whilst failing to control the arteries congestion will be caused below the tourniquet This results in an *increase* rather than a decrease of the hæmorrhage A tourniquet therefore requires to be applied firmly and effectively Failure to observe this essential is a common error which is to be avoided at all costs

3 **Excessive pressure**—There is no point in tightening a tourniquet beyond the stage where hæmorrhage is stemmed Pressure beyond this effective point will be expended on the soft tissues the muscles nerves and blood vessels Nerve trunks are particularly susceptible to injury and the vicious compression which can be applied by a tourniquet frequently causes a paralysis This is particularly true in the upper arm where the musculo-spiral nerve is mostly affected, probably on account of its proximity to the shaft of the humerus Excessive pressure may affect the blood vessels by causing injury to the lining endothelium with the result that thrombosis may occur after the tourniquet is released

4 **Imperfect fixation**—The slipping of a tourniquet or of its tightening apparatus such as the twisting rod, may well prove disastrous If reliance is placed upon a pad to compress the main vessel this danger is magnified, as movement may cause the artery to roll from beneath the pad and liberate itself

5 **Prolonged fixation**—The period of application of a tourniquet is limited The actual period will vary with the original state of nutrition of the tissues and with the devitalizing effect of the injuries which they have sustained

6 **Undue manipulation**—Manipulation of a wounded extremity adds to the effects of the injury and to shock Therefore there is a distinct advantage in using a tourniquet which can be applied with the minimal amount of

which contains a slotted rod through which the webbing threads This rod may be rotated within the frame by turning a milled knob to which it is geared by a worm drive

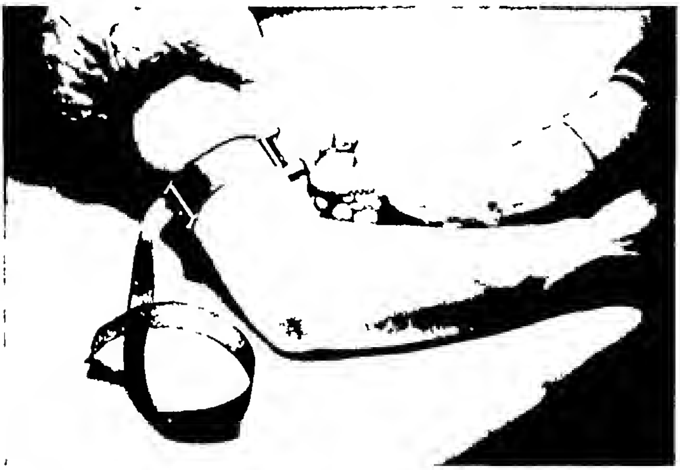

Fig 170
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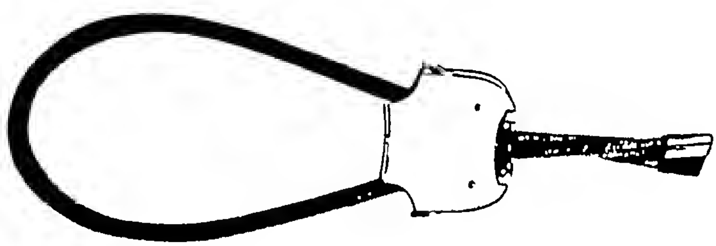

Fig 171
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Fig 172
The L P L tourniquet applied to arm.

CHAPTER XXI

EXPOSURE OF THE MAIN VESSELS OF THE LIMBS

CLASSICAL approaches to the vessels of the limbs find little or no place in the surgery of the vascular injuries of war Missiles do not inflict their damage conveniently at the seats of election they have no respect for the surgical accessibility or otherwise of the wounded vessel and so it comes about that the standard exposures of the operative surgery classroom are both dangerous and inadequate

A generous exposure helps the surgeon to overcome many difficulties and allows him to complete the operation with dispatch. It is desirable that the injured vessels should be displayed for a good distance above and below the lesion and it is essential that the incision should permit inspection and identification of adjacent structures particularly nerves The experience of the 1914 18 war showed that it was possible to secure adequate access to all the commonly injured vessels and yet pay due regard to the preservation of the surrounding anatomy or at least reduce to a minimum the degree of interference with important structures In this connection tribute must be paid to the work of Fiolle and Delmas who towards the end of the last war established many of the techniques which have been followed in this chapter and to Sir George Makins for his comprehensive and invaluable scrutiny of all the problems of vascular surgery which confronted British military surgeons

SOME GENERAL CONSIDERATIONS

In many of the primary and secondary operations on wounded blood vessels a bloodless operative field is necessary and the following methods are in use to control the circulation temporarily —

1 Tourniquet
2 Provisional ligature { (a) By tape; (b) Over rubber tubing

In the case of wounds of the limb vessels, save those at the root of the limb the application of any one of the usual types of external tourniquet is admirable For vessels at the root of the limb—*e g* the common femoral and the axillary—the method of provisional ligature has to be employed The method as a rule does not demand a further incision especially if the large dissections advocated here are adopted Nevertheless when the femoral is injured close to the inguinal ligament or the axillary artery is wounded near its commencement separate exposure of the external iliac or of the subclavian arteries may occasionally be advisable movement. Several of the patterns described in this chapter can be applied over the clothing, even over thick flying kit.

7. **Local skin effects**—Pressure of a tourniquet is borne by the skin. Narrow tourniquets, in particular, cause much bruising, and may result in sloughing of the integument. Nipping of the skin during the manœuvre of tightening the tourniquet adds greatly to the pain. Correct technique during its application and the provision of protective material between the tourniquet and the skin obviate these untoward effects.

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medius and runs forwards between that muscle and the gluteus minimus to the anterior superior spine while the lower passes directly forwards towards the great trochanter

THE INFERIOR GLUTEAL ARTERY leaves the pelvis through the lower part of the great sciatic foramen and lies below the pyriformis muscle It descends to the thigh along the postero-medial side of the sciatic nerve

THE INTERNAL PUDENDAL ARTERY also leaves the pelvis through the lower part of the great sciatic foramen, but medial to the inferior gluteal vessels. It too, appears at the lower border of the pyriformis, and after a short course across the ischial spine it passes forwards through the lesser sciatic notch into the perineum.

Each of these vessels is accompanied by corresponding venae comites and the nerves of the same name are in close proximity

EXPOSURE OF THE VESSELS OF THE BUTTOCK

Surgical considerations—The operation is generally undertaken for subgluteal hæmatoma or aneurysm and it is seldom possible to localize the lesion to one or other of the vessels before operation Furthermore the close propinquity of important nerve trunks makes anything in the nature of blind surgery hazardous in the extreme The ideal method is to expose all three vessels simultaneously and in such a way that damage is not inflicted on the nerves These requirements are fulfilled in the operation of Fiolle and Delmas

Position of the patient—The patient lies on the abdomen with a flat pillow under the pelvis on the affected side An assistant should be detailed to hold the leg he slips his hand beneath the knee and gently extends the hip-joint at the same time laterally rotating the thigh These steps relax the gluteal muscles

The incision begins at the middle of the lateral surface of the great trochanter passes up to a point an inch above the trochanter and then curves gently towards the posterior superior iliac spine

The dissection—In the upper part of the incision the thick fat covering the gluteus maximus is exposed and cleared away until the fascia covering the muscle is clearly demonstrated In the lower part of the wound the strong white fascia covering the trochanter —the upper part of the ilio-tibial tract—is exposed

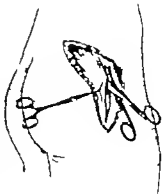


FIG 176

Showing the incision and division of the ilio-tibial band, which is divided with in the length of the incision.

The interval between the gluteus maximus and the deeper muscles i e the plane of the vessels is occupied by loose connective tissue which renders the separation of the gluteus maximus easy if the proper line of cleavage is established The only way to do this without difficulty is to begin below The ilio tibial band is divided over and above the great trochanter in the line of the skin incision (Fig 176) A bursa is generally opened as this step is carried out A finger is now passed under the divided fascia and pushed upwards and medially in the space beneath the gluteus maximus The muscle is lifted up by the finger until its upper border is clearly visible through the fascia which covers it and the surface of the gluteus medius Keeping the muscle lifted off the deeper structures its upper edge is freed by cutting through the fascia in a line from the great trochanter to the iliac crest

The principal disadvantage of provisional ligature is the additional trauma which it may inflict on the vessel above the site of the original injury, and which may lead to the occurrence of thrombosis or to secondary hæmorrhage The simplest and least damaging method is that in which a tape is simply passed round the artery and held moderately taut by the assistant By this method, however, the surgeon is deprived of the benefit of his assistant's hand—and sometimes of his attention Gordon-Taylor has therefore advised occlusion of the vessel by a broad tape knotted over a piece of rubber drainage tube placed alongside the artery (Fig 173) In this way the vessel is protected from contact with the knot—the most injurious part of the ligature A modification of this method has been used by the writer A piece of drainage tube is slit along one side and then applied as a sheath to the whole circumference of the vessel The ligature—broad tape or ribbon gauze or gut—is then applied over the rubber guard (Fig 174)

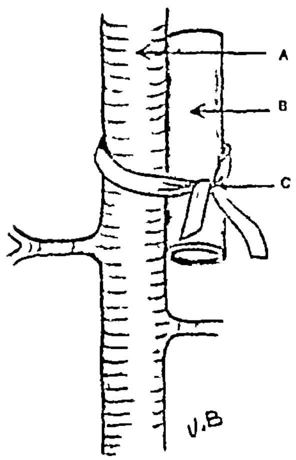


Fig 173
Temporary occlusion of a large artery by Gordon-Taylor's method A, Artery B, Rubber drainage tube C, Tape tied with a single turn

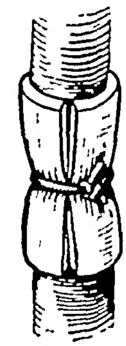


Fig 174
Author's method of temporary occlusion of an artery A ligature is applied over a piece of split rubber tubing

The use of arterial clamps is both clumsy and more traumatizing, and should be avoided Crile's screw-clamp (Fig 175) is the most popular form, but a simple temporary type can be improvised by ensheathing the blades of an ordinary hæmostat with closely fitting rubber tubing

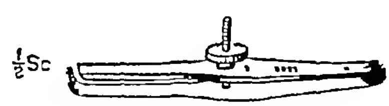


Fig 175
Crile's clamp

THE GLUTEAL ARTERIES

The principal vessels of the gluteal region are placed deeply beneath the considerable mass of the gluteus maximus, they are the superior and inferior gluteal and the internal pudendal arteries All are branches of the internal iliac, and they reach the buttock through the great sciatic foramen In injuries close to the bony margin of the foramen it may be necessary to ligate the internal iliac artery in order to control the bleeding

Anatomy—THE SUPERIOR GLUTEAL ARTERY emerges through the upper part of the great sciatic foramen and lies above the pyriformis muscle Between the contiguous edges of this and the gluteus medius muscle it breaks up into a superficial division, which almost immediately terminates in numerous branches on the deep surface of the gluteus maximus, and a deep division, which in turn divides into upper and lower branches The upper arises from the trunk under cover of the gluteus aneurysms of the artery or arterio venous aneurysms for secondary hæmorrhage from septic wounds in the proximal part of the thigh and for temporary or permanent arterial occlusion in high wounds of the femoral artery and aneurysms of the upper part of the femoral vessels It should be noted that ligation of the external iliac artery is not generally followed by untoward effects so far as the limb is concerned and that it often fails to arrest secondary hæmorrhage from wounds of the thigh because the anastomotic circulation is so liberal It should therefore be used in such circumstances only as a last resort

Exposure of the external iliac vessels the choice of methods—The vessel may be approached either by a *transperitoneal* or an *extraperitoneal* route The transperitoneal method is employed for aneurysms of the external iliac artery for it gives the surgeon the opportunity of establishing control of the circulation by placing a provisional ligature either around the common iliac or the very origin of the external branch In aneurysms of the femoral artery which reach upwards to or extend beyond the inguinal ligament the transperitoneal method may also be the more convenient

In the other cases the extraperitoneal approach is the method of choice and in practice is the more frequently used

EXTRAPERITONEAL EXPOSURE (ASTLEY COOPER'S METHOD)

Position of the patient—The patient should be placed in the Trendelenburg position

Incision—The incision begins at a point immediately lateral to the external abdominal ring and is carried laterally parallel to and half an inch above the inguinal ligament Opposite the middle of the ligament it curves gently upwards towards the anterior superior iliac spine

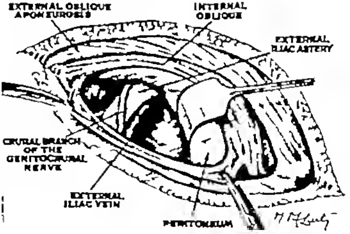


Fig 178

Extraperitoneal exposure of the external iliac vessels.

Dissection — The aponeurosis of the external oblique is exposed and divided in the line of the incision the inguinal canal in consequence being opened The lower border of the conjoint tendon is defined and a finger passed under it to stretch the internal oblique fibres which arise from the inguinal ligament These fibres are divided close to the ligament and retracted at the lateral part of the wound the fibres of the transversus muscle are also divided in the line of the incision The fascia transversalis and the spermatic cord are now disclosed with the inferior epigastric and the deep circumflex iliac vessels visible through the fascia The epigastric artery on leaving the external iliac passes upwards and medially the deep

The muscle is now drawn backwards and medially with a large flat retractor (Fig 177). Branches of the superior gluteal artery which penetrate the muscle are made tense by this, and may require to be ligated

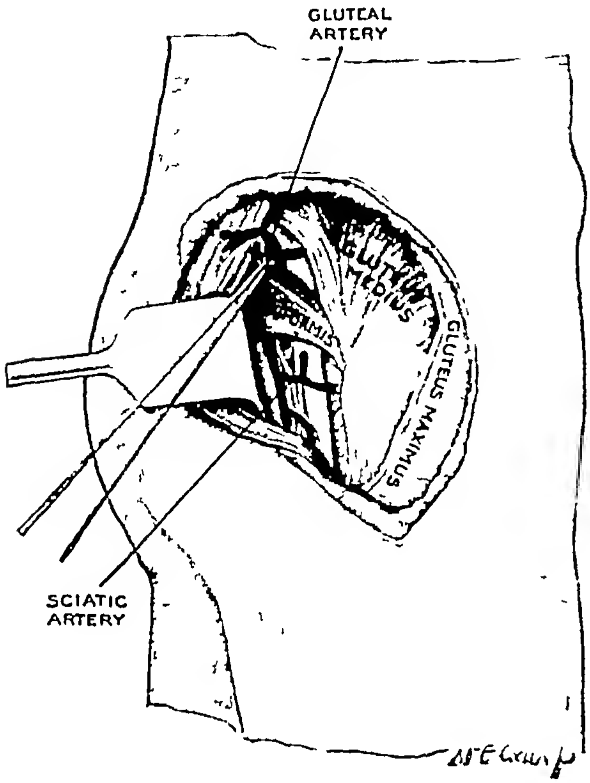


FIG 177
Exposure of the gluteal and sciatic arteries The underlying structures seen on retraction of the gluteus maximus (*After Fiolle and Delmas*)

The muscles, vessels and nerves of the buttock are now displayed after the blood clot is cleared away, in stout individuals it may also be necessary to clear away by gauze dissection a considerable amount of fat

The vascular trunks should be explored in turn To do this the pyriformis muscle is first identified At its lower border there are found the following structures, from the lateral to the medial side—the large, white sciatic nerve trunk, the smaller inferior gluteal and posterior cutaneous nerves, the inferior gluteal artery and vein, the nerve to the obturator internus muscle, the internal pudendal artery and veins and the pudendal nerve Retraction or division of the pyriformis may enhance the exposure of the vessels

Above the pyriformis the superficial branch of the superior gluteal artery is exposed In order to investigate its deep branch and the main trunk, the gluteus medius must be separated by blunt dissection from the upper border of the pyriformis, and retracted The deep branch is then clearly visible and it is a simple matter to trace it proximally to the trunk, which can in this way be followed up to its point of emergence from the pelvis

Repair of the wound—Repair is easily effected The gluteus maximus is replaced, and anchored by sutures through the divided fascia and ilio-tibial tract in the line of the incision

THE EXTERNAL ILIAC VESSELS

The external iliac vessels need to be exposed only on rare occasions The operation, however, may be demanded in wounds of the vessels, these are generally situated in the lower half, and especially near the inguinal ligament The diagnosis of such wounds is sometimes difficult, because while the extravasated blood usually collects in the retroperitoneal tissues of the iliac fossa, it may also track downwards into the thigh and be mistaken for hæmorrhage from an injured femoral trunk

The other indications for operation on the external iliac vessels are for injured in addition to the femoral trunk During their course through Hunter's canal the vessels are firmly supported by the adjacent muscles and by the aponeurosis roofing in the canal so that one or both is almost certain to be damaged by missiles which penetrate or perforate this part of the thigh The most dangerous site of all is at the femoro popliteal junction where the vessels pass through the opening in the adductor magnus a fact which coupled with their relative inaccessibility at this point more than justifies the use of a special approach

Wounds of the profunda or circumflex vessels may give rise to hæmorrhage as severe as in injuries of the main trunks and in the upper third of the thigh it is generally impossible to diagnose the site of the bleeding until the vessels are actually inspected Bleeding from venous wounds is usually less extensive since there is a greater tendency to spontaneous arrest On occasion however the effusion may assume the enormous size of the usual arterial hæmatoma

Ligature of the common femoral artery is followed in an appreciable percentage of cases by gangrene of the distal part of the limb This is more likely to happen if there has been a widespread arterial hæmatoma for this exercises a mechanical compression effect on the collateral channels Even when gangrene does not occur the functional capacity of the limb is not infrequently reduced thus coldness œdema on exercise and even trophic changes may occur A large extravasation of blood also favours the development of gas gangrene and predisposes to sepsis which in turn materially increases the risk of gangrene

Certain surgical considerations—This brief review of femoral wounds suggests certain technical considerations While ligature of the femoral artery in civil surgery is usually a simple matter the very reverse is the case in war wounds of the vessel Difficulty is especially met with in dealing with lesions of the artery between the origin of the profunda and the mid point of Hunter's canal because of the large number of muscular branches here and because of the liability of the femoral vein and profunda vessels to simultaneous injury

The risk of gangrene or functional disturbance after ligature of the main trunk is ever present so that it is essential to visualize the exact bleeding points and since it is often impossible to determine before operation which vessel has been wounded there is an imperative need for a wide exposure

The operative methods—In practice femoral wounds should be grouped in two classes—those of the upper two thirds and those of the lower third and of the femoro popliteal junction In the first case an anterior approach in the line of the vessels will generally prove effective both in dealing with the main trunks and also with the profunda and the circumflex branches In the lower situation a special medial approach is advised in order that a fair amount of the popliteal vessels can be brought into the field of operation

EXPOSURE OF THE UPPER TWO-THIRDS OF THE FEMORAL VESSELS

Anatomy—The vein lies to the medial side of the artery and the femoral nerve about half an inch to its lateral side The femoral branch of the genito-femoral nerve l between the artery and the femoral nerve.

circumflex iliac laterally and slightly upwards It may be possible to spare both sets of vessels, but ligation of the inferior epigastric allows the surgeon to displace the ductus deferens more readily, and also indicates the correct plane of cleavage between the transversalis fascia and the peritoneum The finger having identified this plane the fascia is separated from the peritoneum throughout the length of the incision, and then divided, along with the ligamentous fibres which pass from the lower edge of the transversus muscle to the inguinal ligament along the medial side of the abdominal ring (the interfoveolar ligament)

The peritoneum is now gently lifted up off the external iliac vessels and displaced medially until the whole length of them is exposed (Fig 178) The testicular vessels and the ductus deferens which cross the lowest part of the artery are displaced along with the peritoneum

Dissection of the vessels—The vessels run along the brim of the pelvis, first at the medial edge and later, on the surface of the psoas muscle They are enclosed in a well-marked fascial envelope, and since the external iliac vein is closely applied to the medial side of the artery, the sheath should be incised from the lateral side The femoral nerve is about half an inch lateral to the artery When the upper parts of the vessels are being exposed care should be taken not to injure the ureter which crosses the artery near its origin The genito-femoral nerve lies in front of the artery and must also be protected

TRANSPERITONEAL EXPOSURE OF THE EXTERNAL ILIAC VESSELS

Position of the patient—The Trendelenburg position is again the most suitable

Incision—A paramedian incision which either traverses or displaces the rectus is satisfactory It should extend from the pubis to the umbilicus

The subsequent steps—The small intestine is displaced upwards and kept out of the field of operation by gauze packs The subsequent steps differ on the two sides

A *On the right side* the artery is identified by palpation as it runs along the pelvic brim, and the parietal peritoneum incised directly over it The outer leaf of the peritoneal wound is separated by blunt dissection and retracted The ureter is usually stripped off the vessel along with the peritoneum

B *On the left side* the pelvic mesocolon overlies the artery If the colon is long, and has a long mesentery, it can be turned upwards so that the intersigmoid fossa is obliterated In this event the mesocolon is drawn away from the vessel, and its exposure can be carried out as on the right side

When the sigmoid is short and the mesocolon tight, the above manœuvre is not possible In this case the sigmoid colon is drawn downwards and laterally so as to spread out its mesentery The position of the sigmoid arteries is defined, and an incision is made downwards through the mesentery from the level of the sacral promontory, at a distance of about two inches from the mid-line The incision must not approach nearer the bowel than one and a half inches lest the marginal arterial arcade be damaged The artery is now displaced through the window in the mesocolon

Alternatively an incision may be made in the peritoneum alongside the colon, and the colon and posterior parietal peritoneum stripped medially off the posterior abdominal wall until the vessel is displayed

THE FEMORAL VESSELS

Wounds of the femoral vessels are among the most common and the most difficult of the vascular lesions of war Certain parts of the vessel are rendered especially vulnerable because of the anatomical arrangements, thus the common femoral artery is fixed at its origin under the inguinal ligament, and also at the origin of the profunda, while the vein is similarly anchored by its great saphenous tributary Wounds in this situation are therefore frequent and may be very severe, and it must be borne in mind that the profunda artery or one or both of its circumflex branches may be injured in addition to the femoral trunk. During their course through Hunter's canal the vessels are firmly supported by the adjacent muscles and by the aponeurosis roofing in the canal so that one or both is almost certain to be damaged by missiles which penetrate or perforate this part of the thigh. The most dangerous site of all is at the femoro popliteal junction where the vessels pass through the opening in the adductor magnus a fact which coupled with their relative inaccessibility at this point more than justifies the use of a special approach.

Wounds of the profunda or circumflex vessels may give rise to hæmorrhage as severe as in injuries of the main trunks and in the upper third of the thigh it is generally impossible to diagnose the site of the bleeding until the vessels are actually inspected. Bleeding from venous wounds is usually less extensive since there is a greater tendency to spontaneous arrest. On occasion however the effusion may assume the enormous size of the usual arterial hæmatoma.

Ligature of the common femoral artery is followed in an appreciable percentage of cases by gangrene of the distal part of the limb. This is more likely to happen if there has been a widespread arterial hæmatoma for this exercises a mechanical compression effect on the collateral channels. Even when gangrene does not occur the functional capacity of the limb is not infrequently reduced thus coldness œdema on exercise and even trophic changes may occur. A large extravasation of blood also favours the development of gas gangrene and predisposes to sepsis which in turn materially increases the risk of gangrene.

Certain surgical considerations—This brief review of femoral wounds suggests certain technical considerations. While ligature of the femoral artery in civil surgery is usually a simple matter the very reverse is the case in war wounds of the vessel. Difficulty is especially met with in dealing with lesions of the artery between the origin of the profunda and the mid point of Hunter's canal, because of the large number of muscular branches here and because of the liability of the femoral vein and profunda vessels to simultaneous injury.

The risk of gangrene or functional disturbance after ligature of the main trunk is ever present so that it is essential to visualize the exact bleeding points and since it is often impossible to determine before operation which vessel has been wounded there is an imperative need for a wide exposure.

The operative methods—In practice femoral wounds should be grouped in two classes—those of the upper two-thirds and those of the lower third and of the femoro popliteal junction. In the first case an anterior approach in the line of the vessels will generally prove effective both in dealing with the main trunks and also with the profunda and the circumflex branches. In the lower situation a special medial approach is advised in order that a fair amount of the popliteal vessels can be brought into the field of operation.

EXPOSURE OF THE UPPER TWO-THIRDS OF THE FEMORAL VESSELS

Anatomy—The vein lies to the medial side of the artery and the femoral nerve about half an inch to its lateral side. The femoral branch of the genito-femoral nerve is between the artery and the femoral nerve.

As the vessels descend, the vein gradually passes behind the artery until finally it is lateral to it The branches into which the femoral nerve divides are for the most part lateral to the artery, but the saphenous nerve crosses the vessels to lie on their medial side towards the lower end of their course

Control of the circulation—Whenever possible, the circulation should be controlled by means of a tourniquet The method of provisional ligature applied above the bleeding point is not satisfactory since there is a free anastomosis between the profunda branches and the branches of the internal iliac on the back of the thigh In high wounds close to the inguinal ligament, however, the application of a provisional ligature to the external iliac must be employed This procedure has already been described (see p 193)

Position of the patient—The patient lies on his back, with the hip slightly flexed, abducted and laterally rotated

Incision—The course of the femoral artery corresponds to a line from a point midway between the symphysis pubis and the anterior superior spine to the adductor tubercle The incision is made in this line

Dissection—The large saphenous vein is exposed and should be preserved, since the femoral vein may require to be ligatured The subcutaneous branches of the artery which come off close to the inguinal ligament—the superficial epigastric, circumflex iliac and external pudendal—are also encountered, with their veins, and may have to be dealt with

The deep fascia is incised in the line of the skin incision, in the upper part of the wound close to the inguinal ligament this step immediately discloses the femoral sheath About two inches below the ligament—at the apex of Scarpa's triangle—the vessels are overlapped by the sartorius muscle The muscle is therefore mobilized by blunt dissection, and retracted laterally in the upper part of the incision, in the lower half it is pulled to the medial side A variation in this latter step may make the dissection easier, however, for if there has been a very large hæmatoma beneath it in the lower part of the wound, the sartorius muscle is so stretched and attenuated that it is more convenient to go through its fibres

After dealing in one or other way with the sartorius, the fibrous roof of the adductor canal which passes from the edge of the adductor magnus to the vastus medialis is incised, and the lower parts of the femoral trunks exposed It should be borne in mind that if there has been much extravasation the vessels will not occupy their accustomed situations, and may be found quite appreciably displaced after the surrounding blood clot has been evacuated

The upper part of the artery and vein are only fully displayed after division and separation of the femoral sheath

THE PROFUNDA AND THE CIRCUMFLEX VESSELS

These must be inspected in injuries of the upper part of the femoral trunk

Anatomy—The profunda arises from the lateral side of the femoral artery about an inch and a half below the inguinal ligament, and passes downwards, backwards and medially behind the femoral artery In the lower part of Scarpa's triangle it passes behind the adductor longus muscle Above this level it is separated from the femoral artery by the femoral vein and its own vein

Exposure of the profunda—To expose the profunda the sartorius is strongly retracted to the lateral side, and the femoral vessels gently displaced medially A network of vessels is then disclosed The lateral femoral circumflex leaves the lateral side of the profunda and passes laterally under the edge of the rectus femoris The circumflex vein passes in front of the profunda to join the femoral vein and large venous tributaries pass across the vessel from the vasti muscles These may require to be ligated to complete the exposure of the profunda and the superficial branches of the femoral nerve have also to be drawn aside An important anomaly of the profunda artery must be kept in mind however This vessel not infrequently arises from the back of the common femoral trunk and when it does so it is more medially placed so that it may be very difficult or impossible to approach it from the lateral side of the femoral vessels It must then be exposed from the medial side

The dissection also demonstrates the usual origin of the lateral circumflex vessel which is itself quite often injured The exposure of the medial femoral circumflex is more difficult The vessel arises from the postero medial side of the profunda and passes directly backwards between the psoas and pectineus muscles on the floor of Scarpa s triangle If the profunda is drawn forwards at its upper end the medial circumflex is rendered more prominent but it may be necessary to divide some fibres of the pectineus to aid in its exposure This step is of little consequence but in any case it will usually be found that in wounds of the medial circumflex vessels the pectineus has already been lacerated by the missile

It is of supreme importance in wounds of the profunda and its branches to ligate the vessels on both sides of the injury The anastomosis which the vessels effect in the back of the thigh is so great that fatal hæmorrhage has been known to occur from the distal ends of the divided vessels

Operations for injuries to these vessels are required more frequently than for any others in the body and it may be laid down as a general statement that with the exception of operations upon the arteries at the root of the neck which possess special dangers of their own no operations call for more capacity and resource on the part of the surgeon than those on the thigh (Sir George Makins)

THE LOWER PART OF THE FEMORAL AND UPPER PART OF THE POPLITEAL VESSELS

Wounds of the femoro popliteal junction are common and make special demands on the ingenuity of the operator The standard methods of approach to the femoral vessels in Hunter s canal and to the popliteal vessels from behind do not either of them alone afford sufficient access to the injured part a combination of the two requires two separate incisions and there is difficulty in securing a satisfactory position of the limb The method of complete exposure of the lower femoral and upper popliteal vessels which was described by Fiolle and Delmas is therefore strongly to be recommended

Position of the patient—The proper positioning of the patient on the operating table is of great importance He is placed on his back and brought as near the edge of the table as possible The thigh is abducted and externally rotated and the hip and knee joints slightly flexed The operator should stand on the medial side of the limb, facing the field of operation The flexed position of the joints relaxes the vascular bundle, while the abduction of the hip renders prominent the tendon of the adductor magnus, which is the only landmark required

Incision—The incision is made from the adductor tubercle, upwards, along the tendon of the adductor magnus for 6 or 7 in

Dissection—The great saphenous vein is exposed, and ligated or displaced, and the deep fascia of the thigh divided The sartorius muscle is identified at the upper part of the wound, it should be mobilized by blunt dissection, and retracted backwards Using the finger, the surgeon now clears the

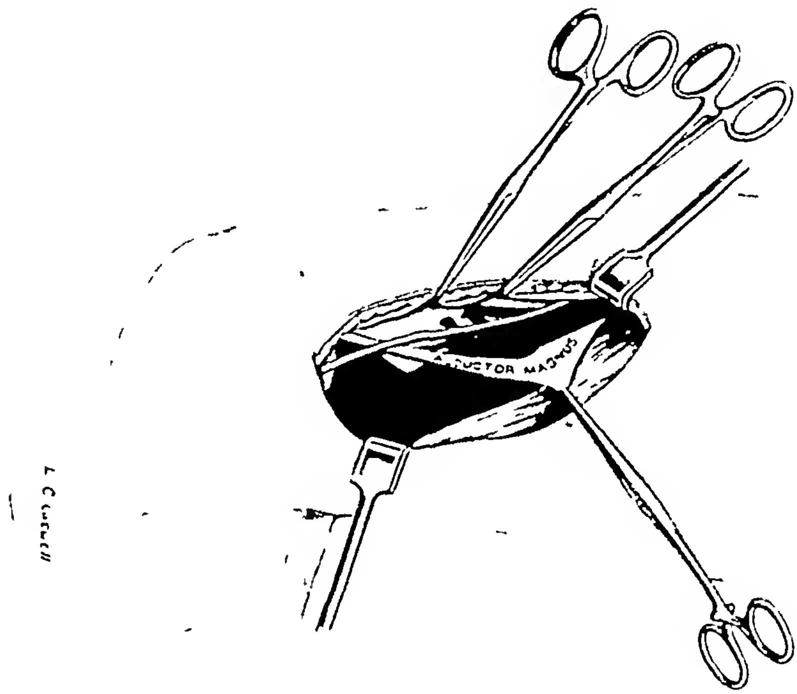


FIG 179

The roof of Hunter's canal has been divided, and retracted laterally with hæmostats A hæmostat has also been applied to the margin of the adductor tendon, which is being drawn medially (*After Fiolle and Delmas*)

posterior surface of the adductor magnus tendon within the limits of the incision, until it is clearly defined The aponeurotic roof of Hunter's canal is next cut, the incision being made close to the lateral margin of the adductor tendon Hæmostats are then applied to the edge of the tendon and to the fascial roof, the tendon is drawn medially and the fascia everted and retracted laterally (Fig 179)

The arterial trunk is now exposed with the vein behind it, and both can be followed from the adductor canal into the depths of the popliteal space The saphenous nerve and the arteria genu suprema leave the lower end of the canal and run downwards in front of the adductor tendon, they are clearly visible in this operation, and should not be injured

Division of the adductor tendon—When the wound in the vessel wall is situated more or less in the vicinity of the opening in the adductor magnus, the control of it by suture or ligature may be facilitated by division of the adductor tendon where it passes like a bridge over the vessels The step is often unnecessary since proximal and distal ligatures can usually be applied above and below the wound but if conservative surgery is contemplated the step is helpful and fully justified since its consequences are not significant

Traumatic aneurysms in this situation are often bilocular with a portion of the sac on each side of the opening in the adductor muscle In such cases division of the tendon is imperative

Repair of the wound—With the removal of the retractors the muscles fall into place and a few stitches suffice to approximate the fascial roof of the adductor canal The tendon of the adductor magnus is stitched if it has had to be cut When drainage is necessary the tube should be passed into the popliteal space through a separate stab incision immediately in front of the medial hamstring tendons

THE POPLITEAL VESSELS

Anatomy—The branches of the popliteal artery are the paired superior and inferior genicular and the single azygos arteries. These are for the supply of the knee-joint and the tendons of the region, and are not capable of much compensatory enlargement; the collateral circulation therefore after popliteal occlusion, is not good

The popliteal vessels like the femoral have an evil reputation among military surgeons for the high incidence of gangrene which follows their occlusion For this reason conservative methods are indicated wherever possible and ligation should be employed only as a last resort The ligature should in all cases be applied immediately above and below the bleeding point which must be demonstrated beyond all doubt to be situated in the popliteal artery itself In view of the great risk of gangrene it is quite unjustifiable to tie off the popliteal artery for bleeding which though occurring in the popliteal space is in fact arising from the commencement of the anterior or posterior tibial branches

EXPOSURE OF THE POPLITEAL VESSELS

Position of the patient—The patient is placed in the prone position, with a small sandpillow beneath the lower end of the thigh to relax the hamstring muscles An assistant should have charge of the limb and should be ready to flex the knee and the ankle in order to relax the calf muscles

Incision—The incision lies in the mid line of the limb and should extend from the junction of the middle and lower thirds of the thigh to a point a hand's breadth below the fold of the knee

Dissection—The small saphenous vein and the sural nerve are encountered in the lower half of the wound The vein is freed and ligated the nerve drawn aside and the deep fascia of the popliteal space exposed and incised The two heads of the gastrocnemius are cleared and separated and at the upper part of the space the semi membranosus is separated from the biceps The vasculo nervous bundle is now displayed In the middle of the popliteal space the tibial nerve lies immediately behind the popliteal vessels as it descends it comes to lie on their postero medial aspect It is gently separated from the vessels and drawn to the lateral side When the upper part of the popliteal vessels is the site of the lesion the nerve should be mobilized as far as its origin from the sciatic at the upper angle of the popliteal space in order to facilitate its retraction At the upper end of the space the vessels are medial to the nerve and nearer to the bone Henry has pointed out that, though "officially" the vessels are not in the popliteal region until they have passed through the opening in the adductor magnus, yet for some distance above this point they are separated from the posterior compartment of the thigh by a very thin screen of connective tissue at the lateral edge of the adductor magnus If necessary, therefore, this can be divided and the very lowest part of the femoral artery exposed as well

EXPOSURE OF THE TERMINATION OF THE POPLITEAL, AND ORIGIN OF THE TIBIAL ARTERIES

The terminal part of the popliteal artery and the origins of the tibial branches can be easily exposed by a simple extension of the above approach In some cases it may be possible to localize the injury to the lower part of the vessel, in which case the upper part of the dissection can be dispensed with and a direct attack made at the lower site

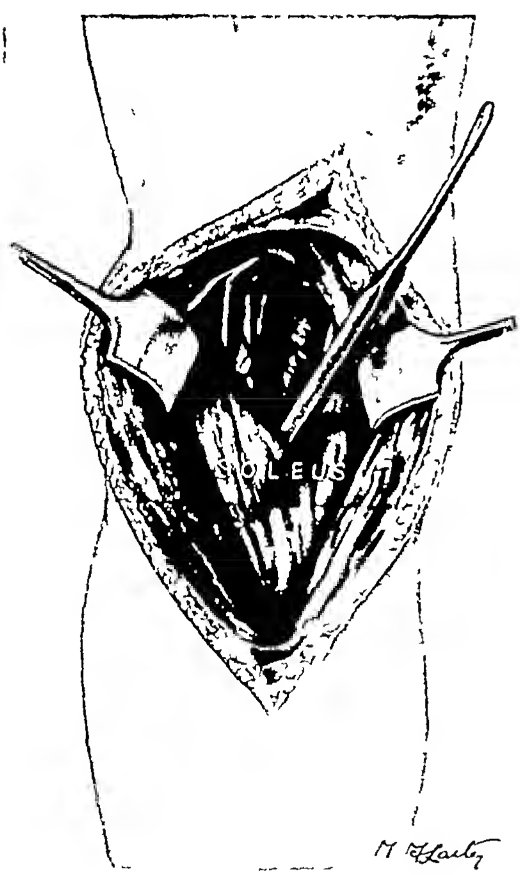


Fig 180

The two segments of the gastrocnemius have been split and retracted A Watson-Cheyne dissector has been passed behind the soleus, which is split likewise This gives a comprehensive exposure of the lower part of the popliteal vessels and the terminal branches

Incision—The incision passes from the fold of the knee downwards in the mid-line as far as the distal end of the bulge produced by the bellies of the gastrocnemius

Dissection—The small saphenous vein and the sural nerve in company with it are retracted to the outer side The interval between the two heads of the gastrocnemius is then defined and the two separated This can be accomplished by the pressure of the finger in the upper part, below, where the fleshy and tendinous fibres intermingle, it requires sharp dissection

The two segments of the gastrocnemius are retracted widely, a manœuvre which is simplified by flexion of the knee and of the ankle The soleus now comes into view, with the tibial nerve and the popliteal vessels disappearing under cover of the fibrous arch at its upper border

The vasculo-nervous bundle is now mobilized, and the upper fibrous margin of the soleus defined, so that a blunt guide can be slipped downwards beneath it (Fig 180) The soleus is split on the guide, the line of division being placed nearer the tibia than the fibula, so that the nerve supply to the muscle is not endangered

The two halves of the soleus are now retracted and the popliteal artery traced downwards to its bifurcation The first part of the anterior tibial branch is identified by its forwards course The posterior tibial is well displayed and the origin of its peroneal branch is also clearly demonstrated

Repair of the wound—A few stitches approximate the adjacent edges of the soleus and gastrocnemius muscles

THE VESSELS OF THE POSTERIOR COMPARTMENT OF THE LEG
(*Posterior Tibial and Peroneal Arteries*)

Anatomy—THE POSTERIOR TIBIAL ARTERY arises opposite the inferior angle of the popliteal space at the level of the tibial tuberosity A line from this point to one midway between the medial malleolus and the medial border of the calcaneum fairly accurately represents its course As it descends it is placed between the superficial and the deep muscles of the calf It lies first on the surface of the tibialis posterior then on the flexor hallucis longus and finally is placed directly on the tibia and the back of the ankle joint It is covered by the gastrocnemius and the soleus in the upper part of its course; in the lower part it lies beneath the skin and the deep fascia only until its termination where it is covered also by the laciniate ligament and the abductor hallucis muscle Apart from its venæ comites the only other important relation of the artery is the tibial nerve which lies at first on its medial side but soon passes behind the vessels to a position on the lateral side Behind the medial malleolus the artery is disposed between the tendons of the posterior tibial and the long flexor muscles medially and the nerve and the tendon of the flexor hallucis longus laterally

THE PERONEAL ARTERY is the most important branch of the posterior tibial, and may itself be the source of considerable hæmorrhage in gunshot wounds of the calf It leaves its parent trunk usually 5 cm below the bifurcation of the popliteal, and passes obliquely towards the fibula, in relation to which it descends to the inferior tibio-fibular joint. Here it ramifies into a series of vessels which are distributed to the lateral and posterior surfaces of the calcaneum and the skin and fascia covering them. The peroneal artery is also deeply placed, generally in a groove between the posterior tibial and the flexor hallucis muscles; occasionally however it is actually embedded in the fibres of posterior tibial muscle

An important anomaly is frequently encountered It consists of reduction in size of the posterior tibial artery or even its complete absence In both cases the peroneal artery is much increased, and in the lower part of the leg it assumes the course of the normal posterior tibial artery

EXPOSURE OF THE VESSELS OF THE POSTERIOR COMPARTMENT OF THE LEG

Position of the patient—The patient is placed face down on the table with the foot supported on a sand pillow in such a way that the ankle joint is plantar flexed and the knee joint flexed In this position the calf muscles are relaxed

Incision—This begins two fingers breadth below the bend of the knee at a point corresponding to the interval between the heads of the gastrocnemius *i e* about half an inch medial to the mid line From here it is continued down first between the heads of the muscle then along the edge of the medial belly to the medial side of the tendo Achillis It ends an inch above the insertion of the tendon (Fig 181)

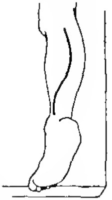


Fig 181 Incision for exposure of the posterior tibial artery

Dissection—After the skin is divided and retracted the short saphenous vein and the sural nerve are mobilized and drawn laterally The superficial calf muscles have now to be divided, and this is made easy if a small button hole incision is made through the fascia at the medial edge of the tendo Achillis close to the proximal end of the tendon A finger passed through this aperture encounters only loose connective tissue and can easily be pushed upwards on the anterior surface of the soleus muscle With the finger maintained in this position as a guide the heads of the gastrocnemius are separated in the mid-line by sharp dissection (Fig 182) and the soleus exposed A short incision is made through the soleus over the point of the guiding finger With its depth thus defined, the muscle is split with scissors exactly in the mid-line (Fig 183), the division being carried up to the tendinous arch at the upper border of the muscle

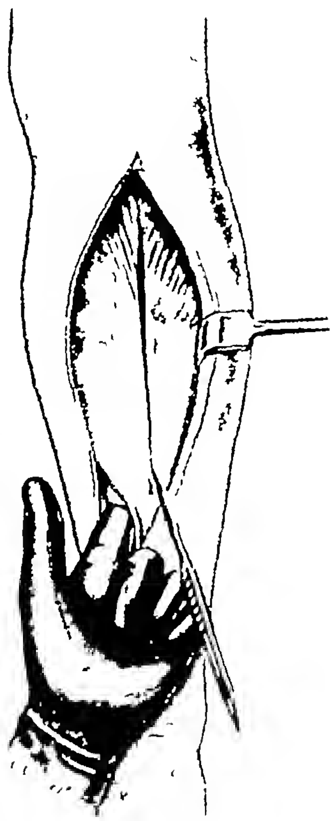


Fig 182

Splitting the gastrocnemius Note that the finger is passed into the cellular tissue beneath the gastrocnemius and the soleus

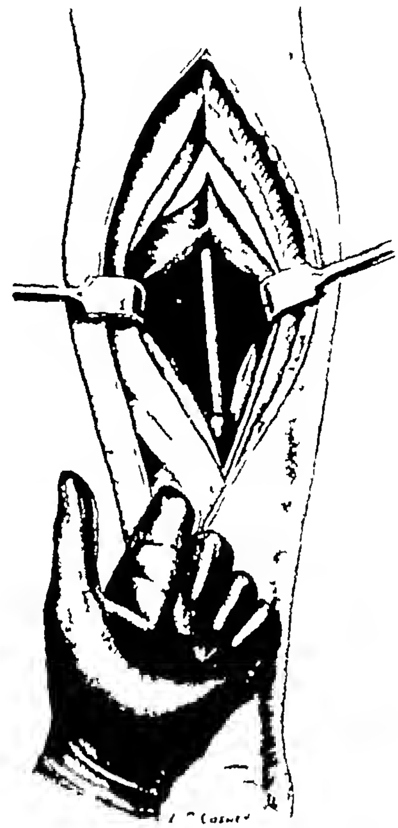


Fig 183

Division of the soleus Again the finger is used to give the correct anatomical plane beneath the soleus (*After Fiolle and Delmas*)

The soleus is a very thick muscle and it possesses a tendinous intersection which stretches across its whole breadth about midway between its anterior and posterior surfaces This is sometimes mistaken for the fascia covering the deep muscles of the calf, but this confusion will not arise if the above method of defining the interval beneath the muscle is employed

The division of the muscles is now continued into the tendo Achillis, and each half strongly retracted The fascia covering the deep muscles of the posterior compartment is now displayed, with the tibial nerve and the tibial and peroneal vessels generally visible through it After division of the fascia the vessels can be mobilized and explored

Repair of the wound—The soleus and gastrocnemius and the tendo Achillis are repaired by a series of interrupted sutures If drainage is necessary—as it usually is in the surgery of war wounds—the tube may be passed upwards under the muscles, through the incision in the fascia alongside the tendo Achillis

EXPOSURE OF THE POSTERIOR TIBIAL ARTERY IN THE REGION OF THE ANKLE

When the posterior tibial artery is wounded in the region of the ankle joint the extensive exposure described above is not required. The method which follows is quite adequate

Position of the patient—This is the same as in the previous operation.

Incision—The incision is parallel to, and a finger's-breadth behind, the medial border of the tibia and extends along the lower third of the leg to the lower border of the medial malleolus.

Dissection—The great saphenous vein and the saphenous nerve are exposed in the superficial fascia. They are retracted. The deep fascia is incised, and the medial edge of the soleus muscle defined and retracted outward and backwards. The fascial layer which clothes the tendons of the deep muscles is next divided, and the artery and its venae comites displayed as they lie directly on the tibia between the posterior tibial and long flexor tendons medially and the tibial nerve laterally. From this point the artery can be traced both upwards and down behind the malleolus. In the latter situation the structures neighbouring the nerve change their relationships to it; thus the flexor digitorum longus tendon lies in front of it and the tibial nerve and the flexor hallucis tendon are posterior to it.

THE ANTERIOR TIBIAL ARTERY

Anatomy—The artery descends on the interosseous membrane to the front of the ankle where at a point midway between the malleoli it becomes the dorsalis pedis artery

In addition to its venae comites, the artery is accompanied by the deep peroneal nerve In the upper third of its course the nerve lies lateral to the artery but inclines medially until in the middle third it is in front of the vessel In the lower third it is again on the lateral si l

The anterior tibial artery (Fig 184) reaches the anterior compartment of the leg by passing downwards and forwards through the upper end of the posterior tibial muscle and over the edge of the interosseous membrane This part of the vessel is very inaccessible The succeeding portion—the proximal third—is also deeply placed between the tibialis anterior and the extensor digitorum longus

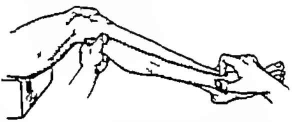


FIG 184

The line of the anterior tibial artery The thumb i placed just anterior to the head of the fibula while the index finger seeks the point midway between the two malleoli.

EXPOSURE OF THE ARCH AND UPPER THIRD OF THE ANTERIOR TIBIAL (DUVAL)

Position of the patient—The patient lies on the abdomen, with the affected limb in a position of slight flexion adduction and medial rotation so that the medial side of the limb is flat on the table

Incision—The incision is made along the lower part of the biceps tendon to the head of the fibula and then across the fibula and vertically downwards on its lateral aspect for half the distance between the lateral malleolus and the fibular head.

Dissection—The deep fascia is divided in the line of the skin incision The biceps tendon is now visible above and below the peroneus brevis the soleus and the lateral head of the gastrocnemius in that order from before backwards. The common peroneal nerve is identified at the proximal end of the incision it lies under cover of the biceps and accompanies the tendon until it sinks into the peroneus longus muscle

The nerve is mobilized and retracted laterally The lateral heads of the

the heads of the gastrocnemius are separated in the mid-line by sharp dissection (Fig 182) and the soleus exposed A short incision is made through the soleus over the point of the guiding finger With its depth thus defined the muscle is split with scissors exactly in the mid-line (Fig 183), the division being carried up to the tendinous arch at the upper border of the muscle

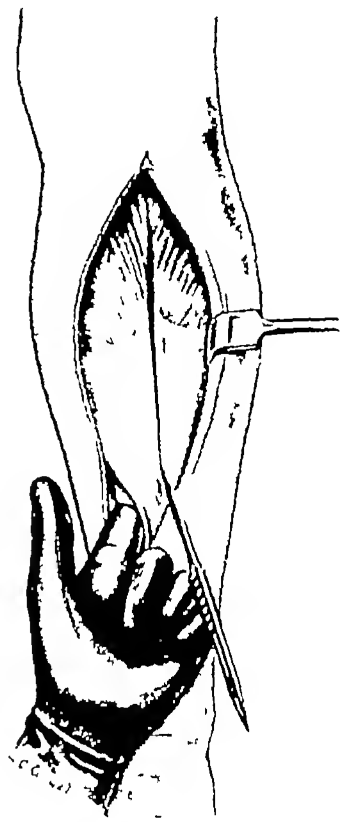


FIG 182

Splitting the gastrocnemius Note that the finger is passed into the cellular tissue beneath the gastrocnemius and the soleus

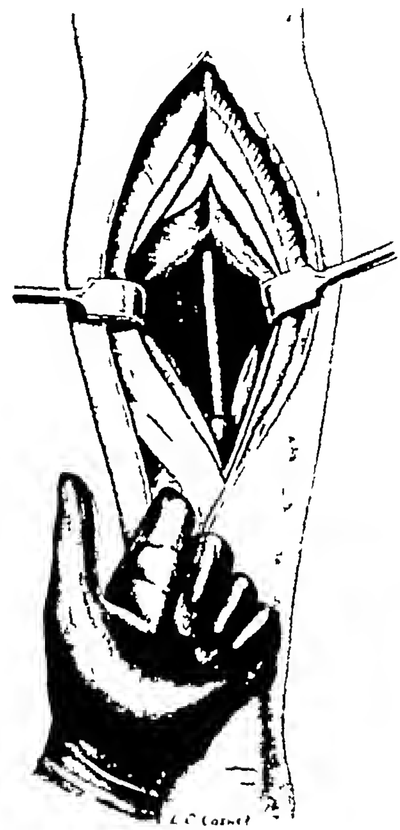


FIG 183

Division of the soleus Again the finger is used to give the correct anatomical plane beneath the soleus (*After Fiolle and Delmas*)

The soleus is a very thick muscle, and it possesses a tendinous intersection which stretches across its whole breadth about midway between its anterior and posterior surfaces This is sometimes mistaken for the fascia covering the deep muscles of the calf, but this confusion will not arise if the above method of defining the interval beneath the muscle is employed

The division of the muscles is now continued into the tendo Achillis, and each half strongly retracted The fascia covering the deep muscles of the posterior compartment is now displayed, with the tibial nerve and the tibial and peroneal vessels generally visible through it After division of the fascia the vessels can be mobilized and explored

Repair of the wound—The soleus and gastrocnemius and the tendo Achillis are repaired by a series of interrupted sutures If drainage is necessary—as it usually is in the surgery of war wounds—the tube may be passed upwards under the muscles, through the incision in the fascia alongside the tendo Achillis

ANTERIOR TIBIAL ARTERY IN UPPER HALF OF LEG

Position of patient—The patient lies on his back

Incision—The skin incision begins in the depression in front of the head of the fibula and is carried downwards and slightly medially in sensibly approaching the crest of the tibia just below the mid point of the leg (Fig 186)

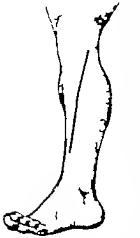


Fig 186

Incision for exposing the anterior tibial artery

Dissection—The dissection begins at the lower end of the wound The deep fascia between the anterior tibial and the long extensor tendons is cut and the plane of cleavage between these muscles defined From below up the two muscles are separated throughout the whole course of the incision using a scalpel to divide the covering fascia and the finger to complete the process

The muscles are retracted widely and the neuro-vascular bundle is disclosed as it lies on the interosseous membrane (Fig 187) The deep branch of the peroneal nerve lies on the lateral side of the artery to begin with but it gradually inclines medially till in the middle of the leg it lies in front of the vessel

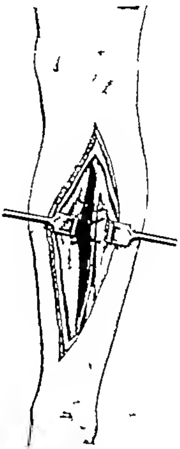


Fig 18

Exposure of the anterior tibial artery

(After F alle ad Delmas.)

THE ANTERIOR TIBIAL ARTERY IN THE LOWER HALF OF THE LEG

Incision—The skin is divided in the line of the vessel

Dissection—In the upper part of the wound the space between the tibialis anterior and the extensor digitorum longus is opened up and after these muscles have been separated the extensor hallucis longus is exposed on the lateral side of the vessel. The tendon of this muscle gradually crosses the vessels to lie on their medial side at the level of the ankle joint It is retracted laterally to complete the exposure of the artery with its venæ comites on each side and the deep peroneal nerve on its lateral aspect

THE DORSALIS PEDIS ARTERY

Incision—The incision runs from a point midway between the malleoli to the posterior end of the first interosseous space

Dissection—Division of the skin discloses the deep fascia, with its powerful thickening, the cruciate ligament, in front of the ankle-joint. The fascia is divided in the line of the incision and the vessel, with the deep peroneal nerve on its lateral side is found in the interval between the extensor hallucis longus medially and the extensor digitorum longus and brevis muscles laterally The artery is crossed close to its termination by the tendinous slip which the short extensor gives to the hallux.

gastrocnemius and soleus muscles are divided across the line of their fibres, and about an inch below their origins In the case of the soleus, this is simplified if a finger is pushed medially under the muscle until it appears in the popliteal space A grooved director is then inserted into this artificial tunnel and the fibres cut on it as a guard.

The director is next pushed into the tunnel which the peroneal nerve makes in the peroneus longus, and the muscle fibres covering the nerve are divided

If the cut muscles are well retracted, the popliteal vessels and the anterior and posterior tibial origins can then be seen The access, however, is poor, until the next step—temporary resection of the fibula—is performed To do this the peroneal nerve is retracted, the neck of the fibula cleared and divided with a Gigli saw The procedure is now repeated at the lower end of the incision, an aneurysm needle is passed round the lateral side of the peroneal muscles, and pushed through the interosseous membrane close to the fibula and from front to back A Gigli saw is threaded in its eye and the needle withdrawn The fibula is then sawn through again and the resected portion drawn laterally to make the interosseous membrane taut (Fig 185) The membrane is divided close to the bone, which can now be tilted downwards and laterally

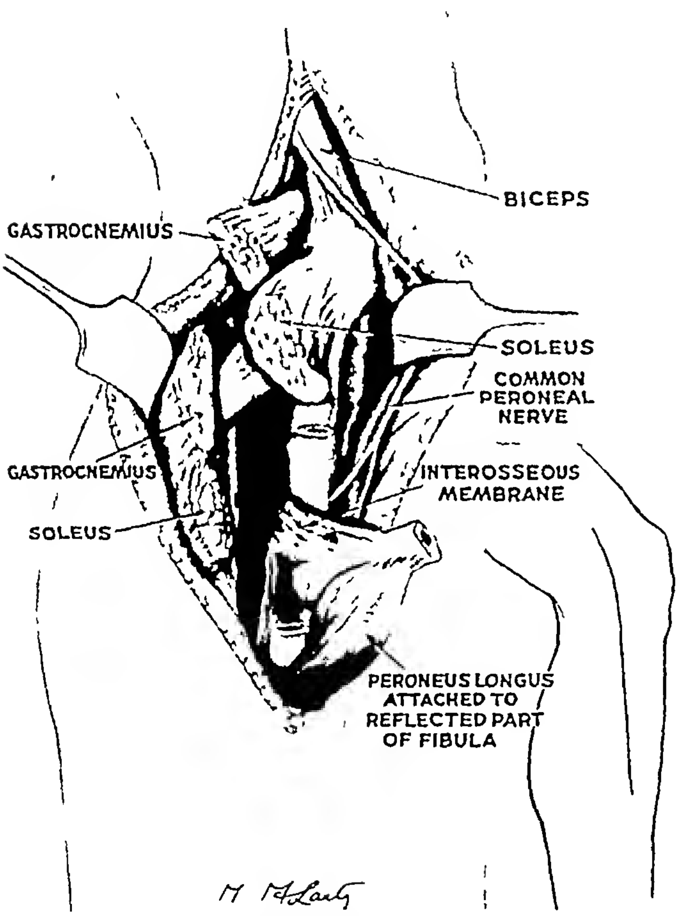


FIG 185

Exposure of the upper third of the anterior tibial artery by temporary resection of a portion of the fibula Inset, the incision

The origin of the anterior tibial artery is rendered freely accessible and the vessel can actually be traced downwards for a couple of inches into the leg

Repair of the incision—The fibular fragment is replaced It is not necessary to fix it, as the periosteum and muscles at the lower line of division are intact and at the upper end repair of the peroneus longus —over the peroneal nerve—secures it The soleus and the gastrocnemius are repaired, and finally the deep fascia stitched in such a way that the peroneal nerve is well covered and protected border and the internal mammary from the lower border The fourth and last branch of the subclavian—the costo-cervical trunk—arises from the back of the second part and runs backwards over the pleural dome

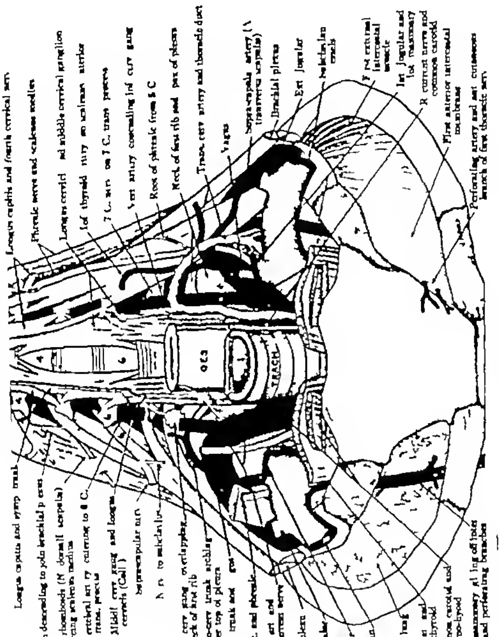


Fig 188

Showing the regional anatomy of the subclavian vessels. (Jamieson.)

The axillary artery in its course through the axilla is deeply placed behind the anterior axillary wall. This consists of two distinct layers, which have both to be thoroughly laid open before the vessel is exposed. The superficial layer is formed by the considerable bulk of the pectoralis major; behind it, the second layer is a compound of the pectoralis minor below and the subclavius above and a well-developed sheet of fascia, the costo-coracoid membrane, between the two

CHAPTER XXII

EXPOSURE OF THE MAIN VESSELS OF THE LIMBS—*continued*

THE SUBCLAVIAN AND AXILLARY VESSELS

OPERATIONS on the subclavian vessels are difficult and dangerous, and demand not only technical skill of a high order but also a thorough knowledge of the anatomy of the root of the neck

Anatomy—THE SUBCLAVIAN ARTERIES enter the neck opposite the sterno clavicular joint The right subclavian leaves the parent innominate trunk here, the left arises directly from the arch of the aorta and has a short intrathoracic course before it appears in the cervical region In the neck each vessel arches laterally reaching in the process a height of about an inch above the level of the clavicle, and finally each disappears behind the middle of the clavicle and enters the axilla at the outer border of the first rib

The subclavian veins are on a more superficial plane than the arteries Each arises as a continuation of the axillary vein at a point corresponding to the middle of the clavicle, and throughout its whole course it lies more or less behind the clavicle Behind the medial end of the clavicle it joins the internal jugular vein to form the innominate vein of the corresponding side The external jugular vein joins the subclavian at the anterior angle of the posterior triangle of the neck it is usually the only tributary

The subclavian vein lies behind the clavicle and the costo coracoid membrane which separates it from the subclavius muscle The vein is anterior to the artery and is separated from it in the medial part of its course by the scalenus anterior muscle The subclavian arteries are each situated deeply (Fig 188) and lie on the anterior aspect of the dome of the pleura and the upper surface of the first rib Above and behind the subclavian artery are the middle and lower trunks of the brachial plexus The scalenus anterior muscle crosses the artery in the middle of its course The segment lateral to the scalene muscle—the third part—is the most superficial part, though even it lies deep to the clavicle at its termination It lies under cover of the deep fascia, and immediately in front is a plexus of veins comprising the transverse scapular and cervical and the external jugular veins The transverse scapular artery is also anterior to it The scalene muscle separates the middle part of the artery from the phrenic nerve, which passes into the thorax on the surface of the muscle, and also from the subclavian vein, at a lower level, and from the transverse cervical and scapular arteries which arise from the thyreo cervical branch of the subclavian

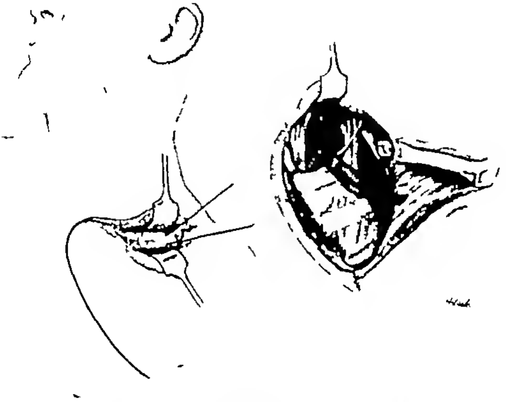
The vessel of the *right side* is somewhat more superficial than the left, for it arises from the innominate, which in turn leaves the aortic arch in a more anterior plane than the left subclavian artery It lies under cover of the sterno-mastoid and the sterno hyoid and sterno thyroid muscles, and has close to it the internal jugular and the vertebral veins, the vagus nerve, the sympathetic cord which loops below and ascends behind the artery to form the ansa subclavia, and the right common carotid artery, in that order from the lateral to the medial side The recurrent laryngeal nerve leaves the vagus opposite its lower border, it then passes below, and ascends behind it to gain the tracheo-œsophageal sulcus

The first part of the *left subclavian* has both thoracic and cervical relationships In the chest it lies behind the common carotid and also the commencement of the innominate vein The vagus nerve and the cardiac and phrenic nerves lie between the two vessels, though, as A K Henry has pointed out, the vagus is more a satellite of the carotid, and its relation to the subclavian is not a close one In addition to the lung and pleura behind it, the artery lies in front of the thoracic duct, but the duct is also placed a good bit medially In the neck, however, the thoracic duct leaves the side of the œsophagus and arches laterally over the origin of the vertebral artery from the subclavian The other cervical relations are substantially the same as those of the right side

The branches which arise from this part of the vessel are the vertebral, the internal mammary and the thyreo cervical trunk The vertebral is the most medially placed as well as the largest The other two lie close to the edge of the scalenus, the thyreo cervical trunk arising from the upper

The skin incision is now continued downwards and laterally towards the axillary fold from the medial end of the horizontal wound The pectoralis major is divided in the line of this part of the incision and beneath the major pectoral the minor is divided close to its thoracic origin Division of these muscles here does not jeopardize their nerve supply

The next step consists of turning the flap of skin muscle and clavicle laterally and to do this it only remains to divide the costo-clavicular



A B

FIG 189

Seneert s method of exposing the first and second parts of the subclavian vessels.

A, Showing the incision and division of the clavicle with a Gigli's saw

B After disarticulation of the sterno-clavicular joint, the clavicle is swung outwards in the flap, and the great vessels at the root of the neck are displayed magnificently

ligament between the clavicle and the first costal cartilage As the flap is retracted care must be taken to avoid damage to the subclavian vein

It is of great practical importance to realize that the vein is *closely attached* to the costo-coracoid membrane and is in consequence expanded when the clavicle is moved forwards This arrangement constitutes a distinct source of danger which can however be obviated with care

With the displacement of the clavicle the great vessels are exposed (Fig 189 B) At the upper and medial part of the wound lies the sternal end of the first rib and costal cartilage with the subclavian vein lying on it The internal jugular vein is seen on the medial side and the vertebral vein in front of the subclavian

Behind and above the artery is displayed very completely so far as its

The cords of the brachial plexus at the apex of the axilla lie on the lateral and posterior aspects of the artery. They then assume an arrangement corresponding to their names—posterior, medial and lateral. The medial cord is between the artery and the axillary vein.

The principal branches of the axillary artery are the thoraco-acromial axis, the subscapular artery and the anterior and posterior circumflex arteries. Injury to either of the first two may closely simulate a lesion of the main vessel, and, because of the collection of blood in the confined space of the axilla, actually lead to obliteration of the radial pulse, thus increasing the possibility of error.

Surgical considerations—It is seldom possible to dogmatize about the part of the vessel actually wounded. In practice it will be found that some 15 per cent. of wounds involve the first part; the other two parts are about equally affected, and in many wounds the vein is simultaneously injured. Coincident damage to the brachial plexus greatly increases the degrees of shock from which the patient suffers, and injury to the pleura may lead to a massive intrathoracic instead of an external hæmorrhage, with consequent delay in diagnosis, and with the production of respiratory embarrassment.

The choice of incision—There is no standard approach for war wounds of the subclavian vessels and their sequelæ, and the choice must be left to the individual operator. In wounds above the inner end of the clavicle it is seldom possible to state with emphasis whether the first or second part of the artery is wounded, or whether the vein is wounded alone or together with the artery. The situation of the wound above the middle of the clavicle may enable the surgeon to diagnose an injury of the third part, or a perforating cervico-axillary wound may help to localize the damage to the end of the subclavian or commencement of the axillary vessels. It is possible therefore, from the technical point of view, to group these exposures into two classes :—

(*a*) Of the first and second parts of the subclavian vessels.
(*b*) Of the terminal part of the subclavian and origin of the axillary vessels.

(a) EXPOSURE OF THE FIRST AND SECOND PARTS OF THE SUBCLAVIAN VESSELS

Sencert's Method of Temporary Resection of the Clavicle

Of the many methods suggested for exposing the first and second parts of the subclavian vessels, the method of Sencert is probably the most generally useful.

Position—The patient lies on his back, with a sand-pillow beneath the shoulders and the face turned to the opposite side.

Incision—A horizontal incision is made parallel to and a short distance above the clavicle, from the outer third to the mid-line. Through this part of the incision the platysma and the deep fascia, and the external jugular vein are divided. Keeping close to the bone, the clavicle is cleared with a periosteal elevator at the junction of the outer and middle thirds, and divided by a Gigli saw (Fig. 189, A). Further medially the sterno-mastoid is divided and the sterno-clavicular joint opened. The ligaments of the joint are completely divided, so as to leave the fibro-cartilage in relation to the sternal surface of the joint.

rib must be cut This tissue contains a branch of the superior intercostal artery so that it must be divided between ligatures

A finger passed directly forwards tangentially to the vertebral body now palpates the artery at a depth of 2 in from the surface Suitable retractors should then be introduced and the artery identified visually with the aid of a good light In any subsequent manœuvres care should be taken to avoid the ansa subclavia which crosses the subclavian immediately beyond the origin of the vertebral branch. If necessary ligatures can be applied to the costo-cervical and internal mammary branches through this incision. The vertebral is also accessible although it is partly hidden by the stellate ganglion. The thyreo-cervical trunk, however is quite inaccessible

Repair of the Incision—Accurate suture of the scapular muscles and the trapezius is the only repair necessary

(b) EXPOSURE OF THE THIRD PART OF THE SUBCLAVIAN AND THE ORIGIN OF THE AXILLARY VESSELS

In affording a wide view of the third part of the subclavian vessels and the upper part of the axillary vessels there is no better method than that of Fiolle and Delmas which not only gives excellent access to the vessels but also to the brachial plexus It is to be noted that a large proportion of vascular injuries in this neighbourhood (45 per cent) are accompanied by lesions of the nerves

Position of the patient—The patient is placed on his back with a sand pillow under the upper thoracic spines The shoulder should project beyond the edge of the table and the arm is supported by an assistant who abducts it to a right angle and laterally rotates it to put the anterior axillary structures on the stretch The face is turned to the opposite side to render the sterno mastoid prominent (Fig 192 A)

Incision — The incision consists of two limbs The first is placed horizontally above the clavicle at a distance of about half an inch from it It extends from the lateral edge of the sterno mastoid outwards for seven or eight inches The second limb begins about an inch from the medial end of the first and it passes downwards to cross the anterior axillary fold close to the arm (Fig 192 A)

Dissection—The lower limb of the incision is deepened first and the pectoralis major displaced (Fig 192 B) The muscle is then divided completely from its clavicular insertion to its tendon this step being facilitated by abduction of the arm to a right angle Some bleeding may be encountered from the pectoral branches of the thoraco-acromial axis but as soon as the muscle is cut the trunk of this vessel can be secured as it passes through the costo-coracoid membrane immediately above the pectoralis minor

With the division of the major pectoral, the deeper layer of the anterior axillary wall is exposed—the pectoralis minor below the costo-coracoid membrane above it and finally the subclavius muscle along the clavicle The membrane is torn through above the smaller pectoral which is then hooked up on the finger and divided as in the radical breast operation

Division of the clavicle—The clavicle is now cleared with a periosteal elevator close to the clavicular head of sterno mastoid and prepared for division As a preliminary a malleable retractor should gently be passed up behind the bone at the site of proposed section Two holes ½ in apart are then drilled from below upwards and the clavicle divided by a Gigli saw (Fig 192 B) or osteotome The retractor protects the subclavian vein from injury during this procedure cervical course is concerned On the right side its origin from the innominate trunk is within the field of operation while the origin of the common carotid is also accessible

If the access is still inadequate, the upper lateral part of the manubrium sterni may be nibbled away after separating the overlying soft tissues

Repair of the incision—The flap is replaced and the pectoral muscles sutured A few stitches through the divided ligaments of the joint, together with repair of the sterno-mastoid, the deep fascia and the platysma, support the clavicle sufficiently firmly If drainage is necessary the tube should emerge through the lower limb of the incision

On the left side the application of a ligature to the first part of the subclavian is a matter of such profound difficulty that A K Henry considers it to be almost impracticable He has therefore planned an approach from behind, where ligation, permanent or temporary, of this part of the left subclavian is likely to be necessary It has the merit both of simplicity and of certainty

THE POSTERIOR APPROACH TO THE FIRST PART OF THE LEFT SUBCLAVIAN ARTERY (HENRY)

Position of the patient—The patient lies in the prone position, with the left shoulder clear of the table and with the arm hanging vertically (Fig 190) A small sand-pillow is placed under the upper part of the chest so that the upper thoracic spine is made as kyphotic as possible

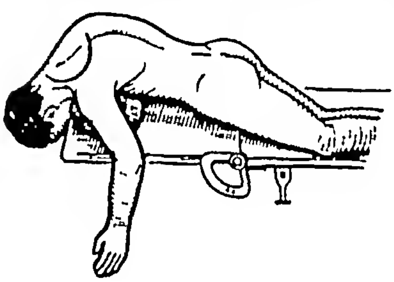


Fig 190

Position of the patient and incision for Henry's method of exposing the first part of the left subclavian artery

Incision—Three points are selected as follows —

1 Four fingers' breadths *above* and one finger breadth to the *right* of the seventh cervical spine
2 Middle of the spine of the left scapula
3 Six fingers' breadths below and one to the *right* of the seventh cervical spine

These points are joined by a curved incision (Fig 190)

Dissection—A flap of skin and subcutaneous tissues is raised and reflected to the right, exposing the trapezius muscle, and at the lower and lateral part of the exposed field, the infra spinatus muscle clothing the angle of the scapula A vertical incision is carried successively through the trapezius, and beneath it, through the rhomboid muscles, and the serratus posterior superior Retraction outwards of these muscles now discloses the splenius capitis

Identification and Division of the Ribs—The body of the first rib passes almost directly forwards, and after the muscles are cut it can sometimes be palpated by a finger hooked deeply down along the neck This is not always possible, however, and it is a simple mistake to take the easily palpable second rib as the first, and then proceed to remove a portion of the third This mistake will be avoided if it is recalled that the first thoracic transverse process lies opposite the seventh cervical spine, and is the first to project beyond the edge of the splenius The second transverse process is now identified and the muscles covering it separated by a sharp elevator until the lamina is laid bare About three inches of the second rib are now similarly cleared The transverse process is cut across at its base, and the rib divided If the proximal end of the rib is now drawn gently backwards, a finger can be passed in front of it to push the pleura away The removal of the rib and the transverse process can then be accomplished without danger by simple torsion until the ligaments of the costo-vertebral joint are disrupted

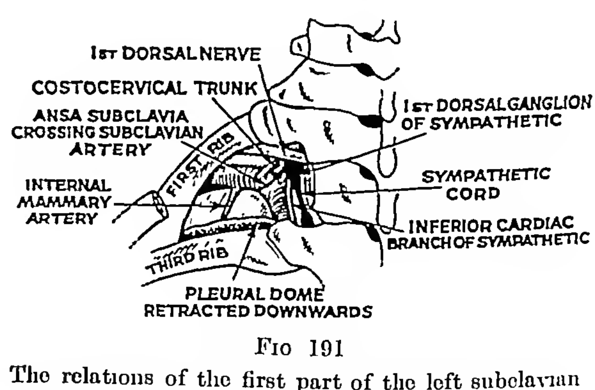


Fig 191

The relations of the first part of the left subclavian artery seen from behind after removal of the second dorsal transverse process and part of the second rib

Exposure of the vessel—The pleural dome must now be displaced downwards and laterally (Fig 191), and to effect this a thin strand of tissue which holds the pleura to the neck of the first upwards and the scalenus anticus identified at the medial part of the wound If it is necessary to expose more of the subclavian artery the muscle can be divided after due care is taken of the phrenic nerve The subclavian and axillary vessels are both surrounded by a tough fibrous sheath derived from the prevertebral fascia of the neck This must gently be divided and cleared in order to mobilize the vessels

It should be noted that while external rotation and abduction of the arm favour the dissection yet the elbow should be kept at least on the same horizontal plane as the body in order to relax the vessels and nerves both in the axilla and in the neck

Restoration of the parts—The assistant raises the shoulder and medially rotates the arm The clavicular fragments thus approximated are secured by a kangaroo-tendon suture or a piece of stainless steel wire The pectoralis minor is coapted by a running suture and finally the pectoralis major carefully and accurately stitched It is not necessary to stitch the subclavius or the scalenus anticus if it has been divided It should be noted that division of the pectoral muscles in the line of the skin incision does not interfere with their nerve supply and in consequence there should be no disturbance of their subsequent function

In cases where drainage is necessary it is better to cater for it by means of a special stab wound in the axilla

The success of this method of approach depends on two all important steps which it might be well to emphasize viz the *complete* division of the pectoralis major and the section of the clavicle as near the medial end as possible

EXPOSURE OF THE LOWER PART OF THE AXILLARY AND UPPER PART OF THE BRACHIAL ARTERIES

Anatomy—The brachial artery begins at the lower border of teres major Its course corresponds to a line from the apex of the axilla to the middle of the fold of the elbow with the arm abducted and rotated laterally In the upper part of its course it lies on the medial side of the humerus and is overlapped slightly by the coraco-brachialis In the lower part it lies in front of the humerus, under cover of the medial edge of the biceps, and at the bend of the elbow it passes under the lacertus fibrosus and enters the forearm

Throughout its course the median nerve is closely related to it, lying first on its lateral side and after the middle of the arm is reached, on its medial side. The ulnar nerve is behind it, and to its medial side but again at the middle of the arm it leaves the artery and passes to the back of the arm. In the upper part of the vessel's course the radial nerve is also a posterior relation until it enters the radial groove of the humerus.

The basilic vein is on the medial side of the artery in the upper half of its course distal to this the vein lies in the superficial fascia which separates it from the artery

Surgical considerations—Exploration of the brachial artery may be required for primary or secondary hæmorrhage in association with wounds alone or with an accompanying fracture of the humerus or with one or more nerve lesions The superior profunda vessels are liable to be injured in the musculo-spiral groove generally along with the radial nerve Ligature of the brachial artery is generally quite successful and the risk of gangrene is small the liability to it is increased if there is a coincident nerve lesion wound infection or if a tourniquet has been left on for a long period prior to operation. Other indications for the exposure of this vessel in war surgery are in cases of threatened ischæmia as a result of traumatic thrombosis or arterial stupor (see p 223) It should be noted particularly that ligation

Exposure of the vessels—If the pectoralis major has been completely divided, the axillary space now falls open like a book under the mere weight

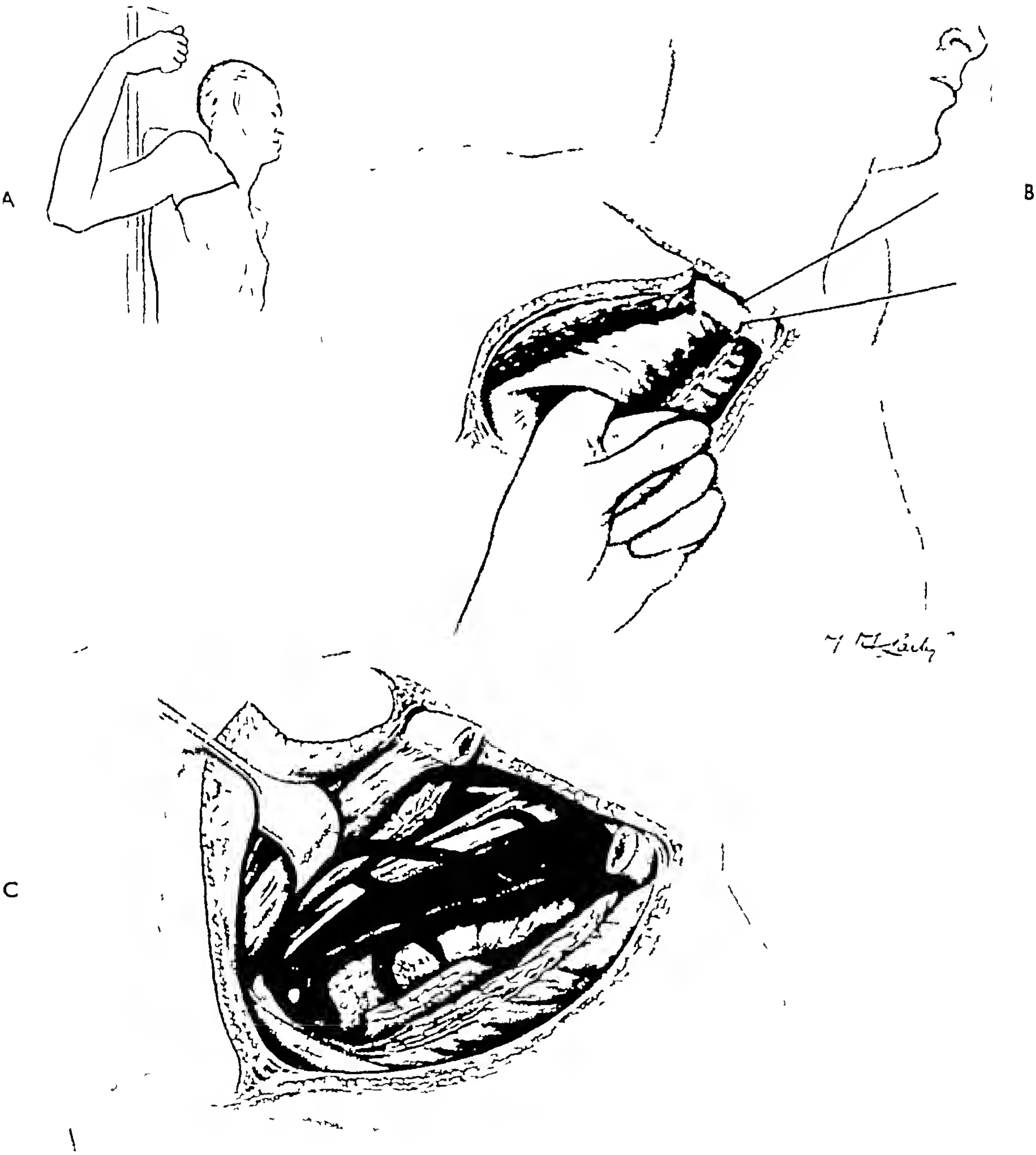


Fig 192
Exposure of the subclavian and axillary trunks by division of the clavicle
(*After Fiolle and Delmas*)

of the arm To complete the exposure of the vessels, however, it is generally necessary to divide the subclavius muscle The axillary structures and the third part of the subclavian artery and the vein are now completely demonstrated (Fig 192, C) The upper flap of the incision is retracted upwards and the scalenus anticus identified at the medial part of the wound. If it is necessary to expose more of the subclavian artery the muscle can be divided after due care is taken of the phrenic nerve. The subclavian and axillary vessels are both surrounded by a tough fibrous sheath derived from the prevertebral fascia of the neck. This must gently be divided and cleared in order to mobilize the vessels.

It should be noted that while external rotation and abduction of the arm favour the dissection, yet the elbow should be kept at least on the same horizontal plane as the body in order to relax the vessels and nerves both in the axilla and in the neck.

Restoration of the parts—The assistant raises the shoulder and medially rotates the arm. The clavicular fragments thus approximated are secured by a kangaroo tendon suture or a piece of stainless steel wire. The pectoralis minor is coapted by a running suture and finally the pectoralis major carefully and accurately stitched. It is not necessary to stitch the subclavius or the scalenus anticus if it has been divided. It should be noted that division of the pectoral muscles in the line of the skin incision does not interfere with their nerve supply and in consequence there should be no disturbance of their subsequent function.

In cases where drainage is necessary it is better to enter for it by means of a special stab wound in the axilla.

The success of this method of approach depends on two all important steps which it might be well to emphasize, viz. the *complete* division of the pectoralis major and the section of the clavicle as near the medial end as possible.

EXPOSURE OF THE LOWER PART OF THE AXILLARY AND UPPER PART OF THE BRACHIAL ARTERIES

Anatomy—The brachial artery begins at the lower border of teres major. Its course corresponds to a line from the apex of the axilla to the middle of the fold of the elbow with the arm abducted and rotated laterally. In the upper part of its course it lies on the medial side of the humerus and is overlapped slightly by the coraco-brachialis; in the lower part it lies in front of the humerus, under cover of the medial edge of the biceps, and at the bend of the elbow it passes under the lacertus fibrosus and enters the forearm.

Throughout its course the median nerve is closely related to it, lying first on its lateral side and after the middle of the arm is reached, on its medial side. The ulnar nerve is behind it, and to its medial side but again at the middle of the arm it leaves the artery and passes to the back of the arm. In the upper part of the vessel's course the radial nerve is also a posterior relation until it enters the radial groove of the humerus.

The basilic vein is on the medial side of the artery in the upper half of its course; distal to this the vein lies in the superficial fascia which separates it from the artery.

Surgical considerations—Exploration of the brachial artery may be required for primary or secondary hæmorrhage in association with wounds alone or with an accompanying fracture of the humerus or with one or more nerve lesions. The superior profunda vessels are liable to be injured in the musculo-spiral groove generally along with the radial nerve. Ligature of the brachial artery is generally quite successful and the risk of gangrene is small; the liability to it is increased if there is a coincident nerve lesion, wound infection or if a tourniquet has been left on for a long period prior to operation. Other indications for the exposure of this vessel in war surgery are in cases of threatened ischæmia as a result of traumatic thrombosis or arterial stupor (see p. 223). It should be noted particularly that ligation of the brachial artery is usually unsuccessful in controlling secondary hæmorrhage from wounds of the forearm

Position of the arm—The arm is abducted and rotated laterally. In this position it should be held, preferably by an assistant or supported on a table beneath the forearm (Fig 193, inset) On no account must the table be placed under the *upper* arm, for the pressure of the table may be sufficient to push the triceps forwards The operator sits facing the inner border of the arm

Incision—The incision runs downwards from the apex of the axilla in the line of the vessel for as far as may be required It overlies, therefore, the medial edge of the biceps Care must be taken not to place the incision too far medially, in the interval between the biceps and the triceps, as then

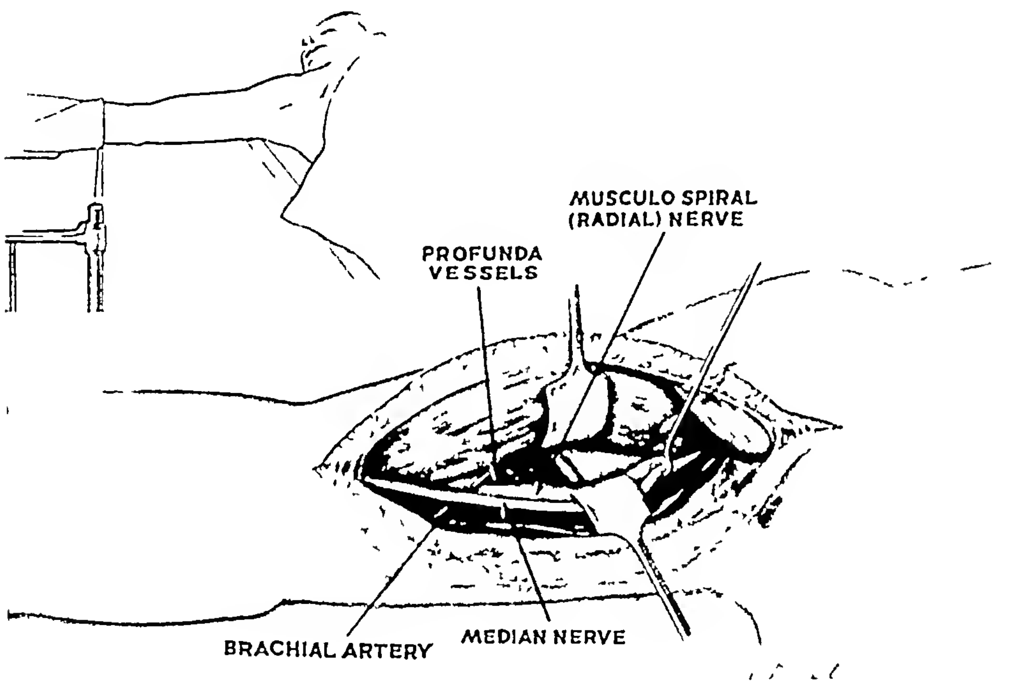


Fig 193
Exposure of the brachial artery and the profunda vessels

the basilic vein may be injured, or even the inferior profunda vessels and the ulnar nerve mistaken for the brachial artery and median nerve

Dissection—At the upper part of the incision the axillary fascia is exposed, and below this the deep fascial envelope of the arm At the lower end of the wound the basilic vein will be seen to penetrate the deep fascia, and its further course can generally be followed through the fascia

The deep fascia is incised along the medial edge of the coraco-brachialis (and not directly over the vessels) The basilic vein is then drawn backwards and medially, and the coraco-brachialis and biceps mobilized and retracted forwards and outwards The neuro-vascular bundle is then displayed and the artery gently separated from the median nerve, and in the upper part of its course from the ulnar nerve as well

Exposure of the branches—The most important branch of the brachial artery is the profunda, which accompanies the radial nerve (Fig 193) If this vessel appears to be the source of hæmorrhage it can be exposed very simply by drawing the brachial artery the basilic vein and the median nerve medially and backwards The radial nerve is now seen on the tendon of the latissimus dorsi and just below this tendon it is joined by the profunda artery which arises from the posterior aspect of the brachial soon after the commencement of that vessel The nerve is lifted forwards and the profunda can be traced to the entrance of the radial groove or even into the groove if the upper fibres of the inner head of the triceps are divided close to the humerus

EXPOSURE OF BRACHIAL ARTERY IN ANTECUBITAL FOSS

Position—The arm is abducted and supported on a side table The elbow should be extended and the limb laterally rotated The surgeon stands on the outer side

Incision—The skin is incised along the medial edge of the biceps tendon

Dissection—The median basilic vein is ligated or elevated and retracted and the deep fascia along the edge of the biceps—including the lacertus fibrosus—is divided If the elbow is now flexed and the biceps retracted the artery and its companion veins are seen on the surface of the brachialis muscle The median nerve lies on its medial side

If this dissection does not afford a sufficiently wide exposure the incision and dissection may be prolonged both upwards and downwards The subsequent steps are then on the lines indicated in the sections preceding and following this

EXPOSURE OF THE TERMINATION OF THE BRACHIAL ARTERY AND THE ORIGINS OF THE RADIAL AND ULNAR ARTERIES

Perforating wounds of the upper third of the forearm may damage either the brachial at its termination or the origin of the radial or ulnar artery The radial artery is comparatively easy to expose here but the ulnar is so deeply placed that it was actually held by no less an authority than Farabœuf to be inaccessible in the first 2 in of its course unless all the flexor muscles arising from the medial epicondyle were divided The following operative technique designed by Fiolle and Delmas gives an excellent display of the whole region

Position of the patient—The arm is abducted and supported on a table The surgeon stands or sits on the outer side of the limb

Incision—Beginning an inch above the fold of the elbow the incision passes downwards along the medial edge of the biceps tendon to its insertion and then curves laterally in the interval between the pronator teres and the brachio radialis to end at the junction of the upper and middle thirds of the radius

Dissection—The median basilic vein which lies transversely in the upper part of the incision is divided between ligatures The deep fascia is then divided along the edge of the biceps tendon together with the lacertus fibrosus The fascial incision is continued into the forearm along the pronator teres

The median nerve is now exposed to view and is explored up to its disappearance between the heads of the pronator teres The brachial artery lies to the outer side of the median nerve, to follow its course the pronator teres is drawn medially and the brachio-radialis laterally This step displays the lower end of the brachial together with the origin of the radial artery which lies under the edge of the brachio-radialis An important branch, the recurrent radial arises from the lateral side of the radial artery and runs upwards on the supinator muscle, passing beneath the radial nerve

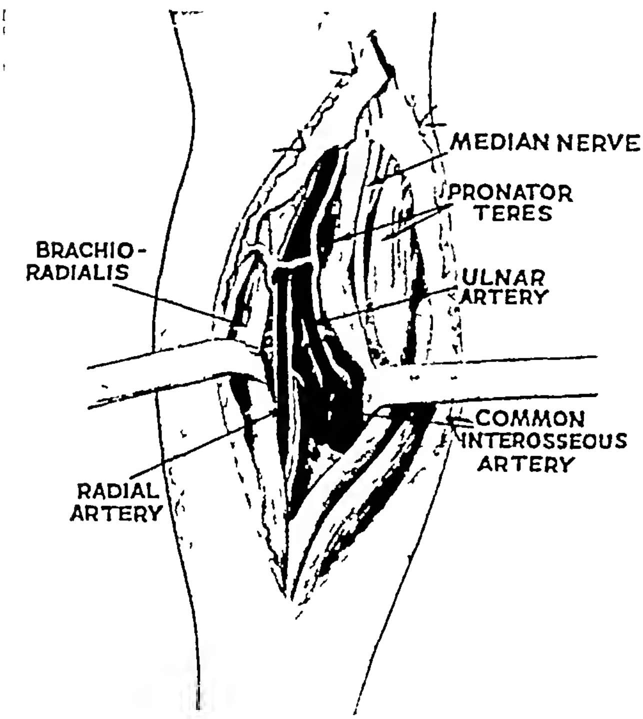


Fig 194

Exposure of the termination of the brachial artery and the origins of the radial and ulnar arteries (After Fiolle and Delmas)

The ulnar artery, which is the direct continuation of the brachial, is more deeply placed To expose it the forearm must be strongly pronated, so that the pronator teres can be very strongly retracted This step gives a wide view of the deeper space (Fig 194), and the artery can be seen passing on to the surface of the deep flexor muscle of the fingers The flexor digitorum sublimis, which lies in front of the vessel, is as a rule sufficiently displaced by the pronation of the forearm to give rise to no difficulty If, as sometimes happens, the upper border of the muscle forms an arch in front of the vessel a few strokes of the scalpel suffice to divide it

The ulnar artery will be found to give origin to two quite considerable branches From its medial side runs the dorsal ulnar recurrent artery which passes up towards the medial epicondyle under cover of the common flexor origin From the lateral side springs the common interosseous trunk, which can generally be followed to its bifurcation into volar and dorsal interosseous arteries The volar interosseous branch of the median nerve lies on its outer side

Repair—The only repair necessary is suture of the fascia and skin

EXPOSURE OF THE ULNAR ARTERY IN ITS LOWER TWO-THIRDS

The course of the ulnar artery in its lower two-thirds corresponds to the lower two-thirds of a line from the medial epicondyle to the pisiform The course of the upper third is indicated by prolonging the line of the lower two-thirds to the middle of the fold of the elbow

Position—The arm is abducted and rested on a side table, with the elbow extended and the forearm fully supinated The medial edge of the forearm should project beyond the edge of the table

Incision—The skin is divided in the line of the vessel

Dissection—The superficial veins are ligated and the deep fascia split in the line of the incision Beginning below the artery is found as it lies under cover of the flexor carpi ulnaris tendon which is drawn medially and backwards (Fig 105) The venæ comites of the artery lie on each side of it and the ulnar nerve is on the medial aspect of the vascular bundle All

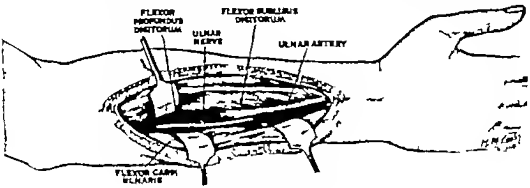


Fig 105

Exposure of the ulnar artery in the forearm.

these structures are covered by a distinct layer of fascia which binds them down to the surface of the flexor digitorum profundus muscle this must be separated and cleared away

In the upper half of the wound the vessels lie deeply placed beneath the fleshy mass of muscle which consists of the flexor carpi ulnaris and the flexor digitorum sublimis These muscles are each firmly attached to a tendinous intermuscular septum which lies between and separates them This must be opened up but no difficulty will be encountered in establishing the proper line of cleavage if the tendon of the carpal flexor has been mobilized below and is now simply followed proximally

EXPOSURE OF THE LOWER TWO-THIRDS OF THE RADIAL ARTERY

The course of the artery corresponds to a line from the middle of the fold of the elbow to the tubercle of the carpal scaphoid.

Position—The arm is abducted and rested on an arm board or a side table with the forearm supinated

Incision—The skin is divided in the line of the artery over the required extent

Dissection—Some of the forearm veins may need to be ligated Thereafter the deep fascia is divided along the edge of the brachio-radialis muscle In the upper part of the forearm the muscle must be retracted laterally to expose the artery and its venæ comites as they pass over the pronator teres on to the surface of the flexor muscles which clothe the radius The radial nerve is in this part of its course separated from the vessels by a considerable

The median nerve is now exposed to view and is explored up to its disappearance between the heads of the pronator teres The brachial artery lies to the outer side of the median nerve, to follow its course the pronator teres is drawn medially and the brachio-radialis laterally This step displays the lower end of the brachial together with the origin of the radial artery which lies under the edge of the brachio-radialis An important branch, the recurrent radial arises from the lateral side of the radial artery and runs upwards on the supinator muscle, passing beneath the radial nerve

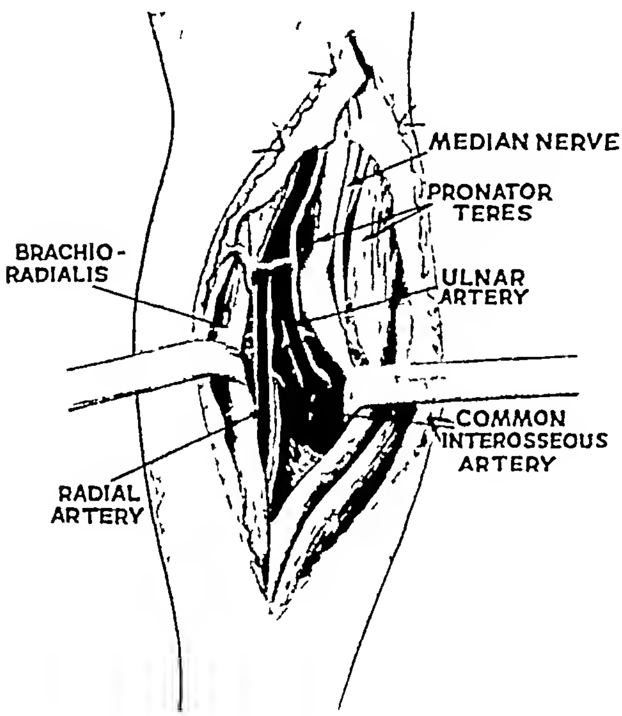


Fig 194

Exposure of the termination of the brachial artery and the origins of the radial and ulnar arteries (*After Tolle and Delmas*)

The ulnar artery, which is the direct continuation of the brachial, is more deeply placed To expose it the forearm must be strongly pronated, so that the pronator teres can be very strongly retracted This step gives a wide view of the deeper space (Fig 194), and the artery can be seen passing on to the surface of the deep flexor muscle of the fingers The flexor digitorum sublimis, which lies in front of the vessel is as a rule sufficiently displaced by the pronation of the forearm to give rise to no difficulty If, as sometimes happens, the upper border of the muscle forms an arch in front of the vessel, a few strokes of the scalpel suffice to divide it

The ulnar artery will be found to give origin to two quite considerable branches From its medial side runs the dorsal ulnar recurrent artery which passes up towards the medial epicondyle under cover of the common flexor origin From the lateral side springs the common interosseous trunk, which can generally be followed to its bifurcation into volar and dorsal interosseous arteries The volar interosseous branch of the median nerve lies on its outer side

Repair—The only repair necessary is suture of the fascia and skin

EXPOSURE OF THE ULNAR ARTERY IN ITS LOWER TWO-THIRDS

The course of the ulnar artery in its lower two-thirds corresponds to the lower two-thirds of a line from the medial epicondyle to the pisiform The course of the upper third is indicated by prolonging the line of the lower two-thirds to the middle of the fold of the elbow

Position—The arm is abducted and rested on a side table, with the

CHAPTER XXIII

WOUNDS OF ARTERIES

WOUNDS of arteries are common in modern warfare When a missile has a high velocity for example a fragment of bomb-casing the damage it causes is so extensive that an artery is very rarely the only structure wounded but in dealing with such a wound the treatment of the vessel comes first because (*a*) continued bleeding to the exterior into the tissues or into a body-cavity threatens life and increases the severity of shock and (*b*) however carefully other damaged structures may be excised and/or repaired the functional result will be *imperfect if the operation on the artery fails to secure an adequate circulation* both locally and distal to the wounded part Defective local circulation predisposes to infection both aerobic and anaerobic defective distal circulation is followed by nutritional lesions which range from reduction in the size and power of muscles to gangrene local or massive It follows that the ideal method of dealing with a wound in an artery is to repair it in such a way that blood flow is maintained when this is impracticable the surgeon must arrange for as many fully dilated collateral channels as possible

TYPES OF TRAUMA

I **Traumatic arterial segmentary spasm (arterial stupor)**—When an artery has been exposed to the disruptive force of a missile without actually being struck it happens occasionally that a *segment of it becomes contracted to such* a degree that the distal pulses disappear Exposure of the vessel shows it to be normal in appearance and microscopical examination of such a segment does not disclose either intimal damage or thrombus The spasm (which lasts for about twenty four hours) is probably due to a local neuro muscular upset in the wall of the artery which leads to reflex vasoconstriction affecting the vessels which would provide collateral channels It may be relieved by inducing peripheral vasodilatation either reflexly or by interrupting the vaso constrictor fibres a test which distinguishes it from actual contusion.

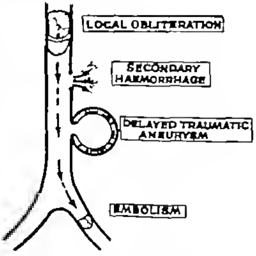


FIG 100
Possible sequels of arterial contusion.

interval, but it approaches them and lies close to them for a short distance in the middle of the forearm. In the lower part of the forearm the vessels are exposed immediately beneath the deep fascia.

EXPOSURE OF THE RADIAL ARTERY IN THE ANATOMICAL SNUFF-BOX

At the lower extremity of the forearm the radial artery winds round the radial styloid process under cover of the abductor and short extensor muscles of the thumb. It then crosses the floor of the anatomical snuff-box and passes under the long extensor of the thumb to reach the proximal end of the first interosseous space.

Position.—The assistant holds the hand by the thumb and fingers in such a way that the thumb is extended and abducted, and the radial side of the wrist is uppermost.

Incision.—An oblique incision is made downwards and backwards from the styloid process of the radius.

Dissection.—The cephalic vein which lies in the subcutaneous tissue over the snuff-box should be avoided; it should be mobilized and retracted.

The deep fascia is divided in the line of the skin incision. The vessel is then exposed, but may be difficult to mobilize because it is firmly bound down to the multangulum major and has a well-marked fascial sheath.

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hæmorrhage are forthcoming, or if there are no indications that the vitality of a distal portion of the limb is becoming endangered. In all such cases although an arterial hæmatoma and subsequently a false traumatic aneurysm may result yet the later treatment of either of these conditions in favourable circumstances for operation is to be preferred to the risks attendant on a primary operation in the front line

It is obvious that the fourth rule is one open to variations under favourable conditions but even then if a large primary hæmorrhage has taken place an expectant attitude is better for both the immediate and remote nutrition of the parts supplied by the wounded vessel

It is possible that in the future such cases may reach a properly equipped hospital more rapidly and then this rule must be modified to conform to the general rules which govern the early excision of wounds It is probable however that in mobile warfare patients of this type should be evacuated as soon as possible

OPERATIONS ON BLOOD VESSELS

General considerations—When it is obvious or possible that a blood vessel has been injured, before the wound is opened up or extended the circulation in the area should be controlled When it can be employed this is best accomplished by a tourniquet The alternatives are proximal pressure

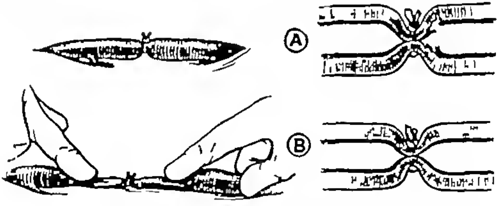


FIG 197

A, Artery tied without first of all emptying it; (right) showing rupture of inner coats.
B Method of emptying ("stripping") the artery during the application of a ligature; (right) showing unruptured coats. (*After Bird.*)

for example on the aorta when the vessels in the groin are affected and temporary occlusion of the vessel proximal to the lesion The latter does not stop collateral circulation thus control of the common femoral does not provide a bloodless field in the thigh However it is sometimes the only method available as in the neck When it is employed, a temporary ligature should be used either applied to the emptied vessel (Fig 197) or tied over a piece of rubber tubing of approximately the same size as the vessel (see p 194) The tension on the ligature must be insufficient to damage the intima particularly in elderly patients

Ligation—When permanent occlusion of an artery is desired it should be divided between ligatures Three are necessary the proximal two 0 5 cm apart the distal 1 cm from the middle the vessel is then severed between

II **Localized contusion**—A bruised artery is always more damaged than inspection of it suggests for the injury affects the inner coats, particularly the intima more extensively than the outer coat As a result (Fig 196)

(*a*) Thrombosis may occur where the intima is cracked or torn The thrombus may obstruct the lumen of the vessel and/or provide emboli which may plug the vessel itself more distally where it is narrower or a distal branch This adds the risk of peripheral nutritional lesions

(*b*) If the wound becomes infected, the weakened part of the wall of the artery may "blow out," leading to secondary hæmorrhage

(*c*) The weak area in the arterial wall may become the starting-point of a traumatic aneurysm

III **Wounds**—An artery may be completely divided or a segment of it removed by a missile following its course Occasionally rifle or machine-gun bullets inflict perforating wounds As a rule the wound is lacerated, and the inner coat much more extensively involved than the outer Transverse wounds alter the alignment of the vessel and give rise to the most profuse bleeding When the patient survives, the outline of the wound is pulled into a circle by the muscular coat, and the endothelium of the intima grows over the edges of the wound to unite with the adventitia If the wound is small enough it may heal as a result of the organization of the clot which plugs it, and the speed of the blood flow within the vessel may prevent the formation of a thrombus Usually however, traumatic arterial aneurysm is the pathological end-result of a simple arterial wound in those who survive long enough

THE CONTROL OF ARTERIAL HÆMORRHAGE

Bleeding from an artery may be temporarily controlled by local or proximal pressure or by the application of a tourniquet Permanent control is established by following the rules included in the "Official History of the War" —

"1 Bleeding vessels in an open wound are always to be ligatured at the earliest possible moment" In certain circumstances it may be necessary to apply forceps to the vessel dress the wound, and evacuate the patient with the forceps in position this plan is better than the prolonged use of a tourniquet

"2 When injured vessels, and especially those of large calibre, are visible in open wounds, they are to be ligatured (or repaired, *J R L*) whether bleeding or not" This rule provides the safeguard against reactionary hæmorrhage When a vessel has been divided completely, both ends of it *must* be found and ligatured When the division is incomplete, and repair is not practicable, the vessel must be divided between ligatures so applied that the injured segment can be removed

"4 When evidence exists that a large vessel has been wounded in the course of a track traversing the body or limbs, unless the conditions are favourable it is not advisable to interfere primarily if no signs of progressing

When smaller arteries require ligation it is not necessary to separate them from any venæ comites

Ligation of the accompanying vein—As a result of experience in the 1914-18 war most surgeons are of the opinion that there is less risk of gangrene following ligature of the dangerous arteries (the common femoral and popliteal) when the accompanying vein is ligatured separately at the same time

Fig 200

Method of anchoring a ligature on the proximal end of a divided artery The stitch shown is passed with a needle (*After Reid.*)

Excision of contused segment—When an artery has been contused (or so wounded that repair is out of the question) the injured segment must be isolated. Two ligatures are then placed proximal to the injured segment and one distal and the intervening bruised tissue removed (*i e.* excised) It has been shown (Leriche) that the contused and thrombosed segment of artery reflexly sets up vasoconstriction in the peripheral vessels including the collateral channels which persists until the initiating focus has been cleanly removed. Moreover by this procedure the complications of local contusion (see Fig 106) are avoided.

Repair of vessels—The suture of blood vessels is not unduly difficult if certain precautions are taken These include gentleness in handling the torn vessels keeping the vessel from drying by the frequent application of sterile olive oil or isotonic (3 8 per cent) sodium citrate solution careful removal from the torn edges or cut ends of the adventitial coat which is a source of thrombokinase and the employment of fine suture material, so inserted as to bring intima to intima by everting the edges The field having been made bloodless the following instruments are required fine scissors (cuticle scissors answer well) safety razor blade for the division of the vessel if necessary medicine dropper mosquito forceps and either special eyeless arterial suture needles or fine arterial needles (Carrel s) threaded with the finest silk To prepare the last the needles are threaded with about 25 cm of silk the suture is wrapped round a small flat piece of wood, placed in a vessel containing liquid paraffin, and sterilized in the autoclave

Wounds—Longitudinal wounds are the most favourable for suture Transverse wounds may be sutured if their extent does not exceed one third of the circumference of the vessel if the wound is larger the division of the artery should be completed, and end to-end suture performed. The adventitia in the neighbourhood of the tear is carefully removed and the edges of the rent neatly trimmed if necessary Somewhat beyond each end of the tear a suture is inserted and tied these act as stay sutures and the needle is left on the one farthest from the operator Tension is put on the stay sutures so as to raise the ends of the wound, the operator holding in his left hand the suture nearest to him while the assistant holds the short end of the other The maintenance of steady traction is of supreme importance as it arranges the edges in eversion and facilitates suturing The surgeon sews towards him using a simple continuous stitch (Fig 201) which extends beyond the wound and is ended by tying it to the stay suture in his left hand Throughout the closure sterile olive oil or sterile the middle and the distal ligatures When the artery is of any size (i e, above the knee and elbow and in the neck), the ligatures should be placed within its sheath This is opened by picking up, with fine-toothed dissecting forceps, a transverse fold of the sheath and slitting this in the long axis of the vessel with the point of a scalpel held back-to-vessel Usually the slit is made in the middle line of the vessel but in the case of the common carotid the nick is made to the inner side, to avoid the descendens hypoglossi nerve First one side of the nick, and then the other is held firmly by forceps, while the artery is separated from its sheath (*not* sheath from artery) by a broad blunt aneurysm needle for a distance of 2 cm When the needle can be made to pass round the vessel, it is threaded and withdrawn not by pulling laterally but by depressing the handle of the needle so that its curve disengages (Fig 198) There is no need to pass the needle from any particular side, provided that the sheath is grasped by forceps on the side from which it is passed The ligatures should be of unabsorbable material suitable material and suitable thicknesses (to be used single) are shown in Fig 199 The artery is now stripped of its contents by the forefingers of an assistant to ensure that the ligatures shall be tightened on the vessel when it is empty By this manœuvre the inner coats of the vessel are preserved intact (see Fig 197), and in sites where the vessel is not already controlled there is no risk of the first loop of the knot being loosened by the pulsations of the vessel while the second is prepared The loops should be tightened with the thumbs or forefingers *close to the vessel* When the wound is not infected, and likely to remain so, the middle ligature is anchored by a fine silk stitch (Reid) passed as indicated in Fig 200 When the wound is infected, it must be left completely open over the site of ligature, so that discharge is not retained.

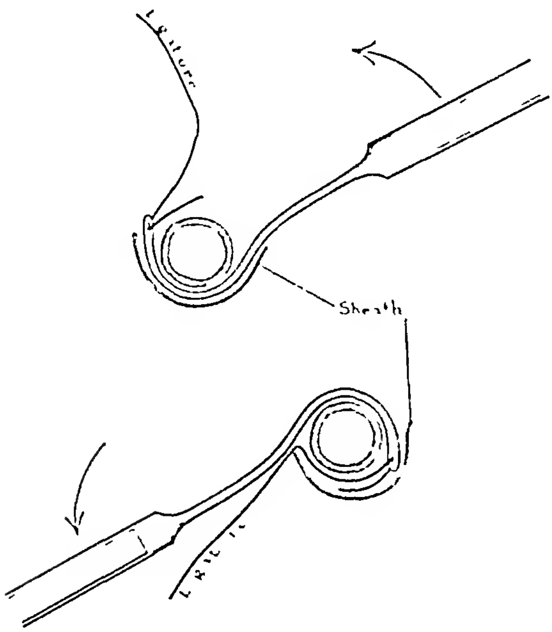
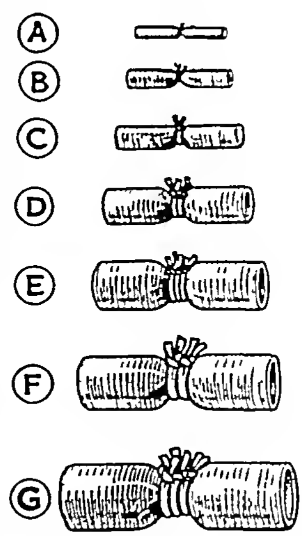


Fig 198
Correct method of withdrawing threaded aneurysm needle



A, Radial artery, one strand of medium silk
B, Brachial artery, two strands of medium silk
C, Axillary artery, one strand of braided silk
D, Subclavian, common carotid, femoral and popliteal arteries, two strands of braided silk
E, Innominate and external iliac arteries, three strands of braided silk
F, Common iliac artery, two strands of tape
G, Aorta, three strands of tape

Fig 199
Material for ligation of arteries (*After Reid*)

When smaller arteries require ligation it is not necessary to separate them from any venæ comites.

Ligation of the accompanying vein—As a result of experience in the 1914 18 war most surgeons are of the opinion that there is less risk of gangrene following ligature of the dangerous arteries (the common femoral and popliteal) when the accompanying vein is ligatured separately at the same time

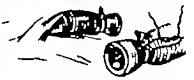


FIG 200

Method of anchoring a ligature on the proximal end of a divided artery The stitch shown is passed with a needle (*After Reid*)

Excision of contused segment—When an artery has been contused (or so wounded that repair is out of the question) the injured segment must be isolated. Two ligatures are then placed proximal to the injured segment and one distal and the intervening bruised tissue removed (*i e* excised) It has been shown (Leriche) that the contused and thrombosed segment of artery reflexly sets up vasoconstriction in the peripheral vessels including the collateral channels which persists until the irritating focus has been cleanly removed Moreover by this procedure the complications of local contusion (see Fig 196) are avoided.

Repair of vessels—The suture of blood vessels is not unduly difficult if certain precautions are taken These include gentleness in handling the torn vessels keeping the vessel from drying by the frequent application of sterile olive oil or isotonic (3 8 per cent) sodium citrate solution careful removal from the torn edges or cut ends of the adventitial coat which is a source of thrombokinase and the employment of fine suture material so inserted as to bring intima to intima by everting the edges The field having been made bloodless the following instruments are required fine scissors (cuticle scissors answer well) safety razor blade for the division of the vessel if necessary medicine dropper mosquito forceps and either special eyeless arterial suture needles or fine arterial needles (Carrel s) threaded with the finest silk To prepare the last the needles are threaded with about 25 cm of silk the suture is wrapped round a small flat piece of wood placed in a vessel containing liquid paraffin and sterilized in the autoclave

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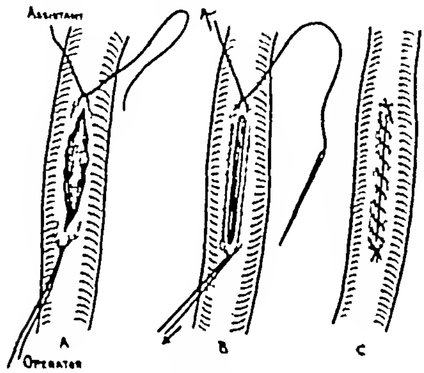

Fig 201

Suture of blood vessel

A, Stay sutures inserted each end of wound B, Tension on stay sutures draws wound together and everts lips Long end of suture farthest from operator on needle ready for continuous suture C, Wound closed

End-to-end anastomosis—Anastomosis is most successful in arteries of medium calibre such as the femoral and popliteal, and it is desirable that it should be employed when possible on account of the relatively insecure collateral circulation in the leg End-to-end union as a primary operation needs a proper setting, proper materials, and a healthy condition of the vessel wall It cannot be employed when there has been much loss of substance, because the anastomosis must be made without tension, and arteries do not stretch nor can they be mobilized to give additional length without dividing important collateral branches which would be indispensable if the repair were not successful The earlier the operation can be performed the better, for after forty-eight hours the anatomical relations are hard to define because of infiltration of the area with blood The use of heparin will help to prevent thrombosis at the suture line The steps of the operation are as follows —

1 The circulation is controlled by a tourniquet the ends of the vessel are identified and freed for 5 cm If a tourniquet cannot be used, each length of the vessel is controlled by a spring clamp, applied as far from the open end as the dissection allows The area is then surrounded with gauze moistened with warm saline solution

2 The ends of the vessel are trimmed evenly

3 The adventitial coat is drawn over each end and cut off with fine scissors This is done by pinching the end of the vessel between the thumb and forefinger, and pulling lightly in the line of the artery

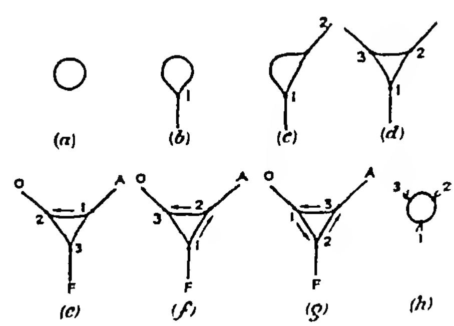

Fig 202

(*a*), (*b*), (*c*), (*d*), Order of placing stay sutures (*e*), (*f*), (*g*), Order of sewing The stay sutures are held by A (Assistant), O (Operator), or fixed by F (Forceps) (*h*) Final position of stay sutures on circumference of vessel

4 The lumen of each segment is washed free of clot and moistened with citrate solution or sterile olive oil , throughout the operation the area is kept moistened in this way, or by dropping heparin solution upon it

5 Three stay sutures are first inserted which bring together equidistant

points on the circumference of the two segments The first of these is placed in the middle of the posterior segments of the vessels (Fig 202 (*a*)) It is tied the needle retained, and a *forceps placed on its short end* (Fig 202 (*b*)) the other stay sutures are caught in forceps about 10 cm between forceps and knot Thus the vessels are arranged as shown in Fig 202 (*c*) and (*d*) in which the order of sewing is also indicated (Fig 202 (*e*) (*f*) (*g*)) All sewing is done towards the operator the original stitch *is used for the whole circumference* as it reaches each stay suture it is fixed by tying it to one of the threads and it is ended by tying it to itself *All sutures are then cut short* A simple over-and-over stitch may be used but this tends to leave too much thread in the lumen The best type is the continuous mattress stitch which brings intima to intima and everts the edges slightly (Fig 203)

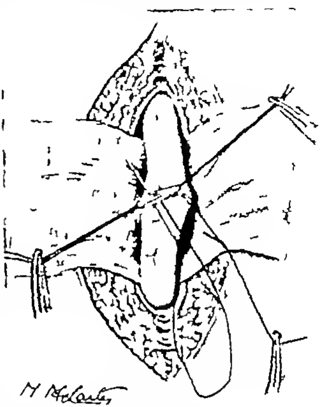

Fig 203

End to-end anastomosis of an artery showing the arrangement of the three stay sutures and the continuous mattress suture which everts the edges

6 The tourniquet is then *released gradually* or *if clamps* have been used first the distal clamp and then the proximal is unfastened

7 Any oozing at the suture line is dealt with by firm pressure with moist gauze or by placing an additional stitch

MAINTENANCE OF NUTRITION

When the flow of blood in a main artery is arrested, the distal parts depend on collateral vessels for their nutrition The volume of blood which can pass by these vessels is proportional to their capacity to dilate In the young adult this is maximal, but in later adult life the arteries begin to lose their resilience and collateral channels may finally become inadequate When a main artery is wounded two factors come into operation immediately which tend to prevent or to delay the establishment of an efficient collateral circulation These are (1) hæmorrhage in the wound which may exert enough direct pressure on the collateral vessels to hinder or prevent the flow of blood in them, and (2) general vasoconstriction of the peripheral vessels due to a reflex initiated by the nerves in the injured segment of artery The presence of either or both crystallizes the surgical problems which are obviously to maintain the nutrition of the limb until operation can be performed, and to secure full vasodilatation in the collateral vessels. The threat of these complications is much greater in the lower extremity than in the upper, as can be seen in the accompanying table, extracted from the figures given in the "Medical History of the War":—

INCIDENCE OF GANGRENE IN SURGERY OF ARTERIES

Artery	Incidence of Gangrene after	
	Wound	Ligation
Subclavian	8.8 per cent	0.0 per cent
Axillary	2.7 ,, ,,	1.1 ,, ,,
Brachial	1.0 ,, ,,	0.0 ,, ,,
Femoral	20.2 ,, ,,	17.2 ,, ,,
Popliteal	31.7 ,, ,,	26.6 ,, ,,

As Sir Thomas Lewis has often pointed out, the application of heat to a limb threatened with gangrene is bad policy, because it increases local metabolism and sets up a demand, which cannot be met, for still further supplies of blood. This policy is seen in its most dangerous form when a limb, occluded by a tourniquet, is heated persistently; in such cases the limb should be allowed to reach the temperature of the environment. When some circulation is left in an extremity, probably the best surrounding temperature to aim at is about 80° F., that is, the temperature of the skin when its vessels are dilated.

The effects of the pressure of local blood clot can be dealt with only by opening up the wound, removing the clot, and dealing with the source of bleeding. The "braking" effect of imposition of vasoconstrictor tone can be obviated in several ways; the physiological basis of all methods is the fact that the collaterals open up suddenly when they are released from the domination of sympathetic vasoconstrictor fibres. This may be accomplished:—

A. **Temporarily**—(1) By heating the distal parts of the extremities, excluding the threatened one. Reflex vasodilatation occurs throughout the body, and the reflex occurs rapidly in the legs when the hands and forearms are heated. The minimum temperature required is about 110° F., and, in the absence of elaborate equipment, may be secured by immersing the hands and forearms in buckets of water at this temperature. (2) By injecting 2 per cent. novocain solution about the appropriate ganglionated sympathetic chain. In practice this can be most often applied to injuries of a lower extremity, when paravertebral injections are made between the second and third, and third and fourth, lumbar vertebræ.

"Injection can be made either with the patient lying flat on his stomach or partly turned on the side opposite the one to be injected. Needles 8 to 10 cm. in length are inserted through the skin 3 cm. lateral to the upper edge of each lumbar spine. When pushed perpendicularly inwards to a depth of 4 to 5 cm. they should make contact with the transverse process of the same vertebra. If bone is not felt at this depth, the direction of the needle must be slightly altered, either upwards or downwards. After the transverse processes have been located, the needle is pointed slightly upwards to pass above the transverse process and inwards at a slight angle towards the mid line. It is then thrust slowly inwards through the psoas muscle until its tip can be felt scraping along the edge of the vertebra.[1] A rubber depth marker (Fig. 204) is of great assistance in measuring the correct depth. Injection made against the sides of the vertebræ and 4 cm. beneath their transverse processes will result in a thorough blocking of the sympathetic rami and the corresponding ganglia with little if any infiltration of the lumbar nerves.

In order to block the second and fourth lumbar ganglia we have inserted needles above the three lower lumbar transverse processes. As in the thoracic region it is important to insert the needles separately from the syringe and then to aspirate each in turn before injection. By observing this precaution the danger of injecting novocain or alcohol into a blood vessel or the subarachnoid space can be averted. 2 c.c. of 2 per cent. novocain adrenalin solution should then be injected through each needle. The rapid warming and drying of the corresponding foot is proof that the needles are accurately placed. (J. C. White.)

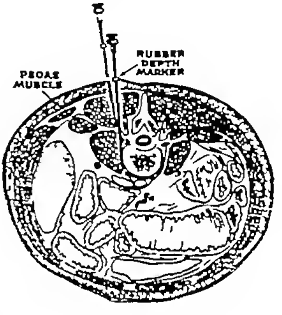

FIG. 204.
Paravertebral injection of lumbar sympathetic ganglia, showing the use of a rubber depth marker. (*After White.*)

B. **Permanently.**—When the femoral or the popliteal artery must be occluded permanently, if the condition of the patient permits, the operation on the vessel should be combined with a sympathectomy, which will provide not only the maximum collateral circulation at the time but also a good insurance for the future nutrition of the limb ten or twenty years afterwards. There are no undesirable sequels, and when this is done it is unnecessary to tie the main vein when the artery is ligated, for it is obviously more physiological to depend upon active rather than passive hyperæmia. The usual extraperitoneal route is employed, and the sympathetic chain is avulsed at the level of the fourth lumbar vertebra.

[1] As the lumbar nerves lie midway between the transverse processes, the needles must be advanced slowly and their direction changed if paræsthesiæ are produced.

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Packing is another somewhat less satisfactory method which can be employed Its main objections are that firm packing in certain situations may obliterate the circulation in the corresponding artery and it invites sepsis

Of course whenever possible the wounded vein should be closed in the orthodox manner by ligation The danger of lateral ligatures has been alluded to such ligatures are inclined to slip and if the venous pressure rises considerably be forcibly thrown off The material used is of importance Catgut lacks tenacity of grip and is unsuitable for lateral ligature Fine silk or linen thread should be used the knot being tied more tightly than is usual with other vascular ligations Careful stitching of the vein wall with stitches tied not too tightly is a highly satisfactory procedure If a fine needle is used the stitches hold well even in friable veins and although the stitch holes bleed, the bleeding can soon be quelled by the application of a hot pack or better still the application of a small piece of muscle Large veins such as the inferior vena cava can be stitched with great facility

The most difficult and dangerous area for venous hæmorrhage is the root of the neck The reader will do well to master Sencert s exposure of the vessels in this situation (see p 212) for use in cases of extreme difficulty

WOUNDS OF CEREBRAL SINUSES

Wounds of the cerebral sinuses are not amenable to suture or ligation Temporary plugging with gauze may be used but is conducive to sepsis in the wounds now being considered One of two plans may be adopted —

1 After the wound in the sinus has been exposed to view by removal of the overlying bone a piece of deep fascia or aponeurosis is applied with shaggy surface downward over the opening in the vein and held in place for a few minutes by pressing with a swab The patch so applied will adhere and effectually mend the hole in the sinus

2 Alternatively the bleeding may be temporarily checked by gauze plugging The toilet of the wound having been completed the skin is sutured the strip of gauze being removed just before the last stitch is inserted.

AIR EMBOLISM

This peril exists chiefly with wounds of the base of the neck and upper thorax and is practically restricted to surgical operations The dangerous area can be defined by two semi-elliptical lines drawn from the apex of one axilla to the other one line passing above and the other below the clavicle (Fig 205)

Suppose a patient to have a deep wound in the root of the neck from

CHAPTER XXIV

WOUNDS OF VEINS

VENOUS hæmorrhage occurring from a limb is controlled so easily by pressure and elevation of the part that in descriptions of wounds of blood vessels this form of bleeding is inclined to be passed over as merely incidental Familiarity with practical surgery soon alters this conception An experienced surgeon will often state that he finds serious venous hæmorrhage more embarrassing than arterial, he refers, of course, to bleeding in certain areas

Serious venous hæmorrhage requiring the mustering of ingenuity and resourcefulness is wont to occur in particular situations, under special conditions —

A **When the patient is straining under the anæsthetic,** particularly if closed gas-oxygen-ether is being used Under these circumstances a vein of even moderate dimensions becomes ballooned, and a small puncture of it produces alarming results With the intravenous pressure thus raised, a lateral ligature can be blown off and what was a small puncture becomes a veritable gap

B **When a wounded vein has been surrounded for some time (forty-eight hours or more) by blood and blood clot**—Especially if this is even mildly infected, the vein wall is apt to become friable—sometimes so friable that a ligature cuts through

The anatomical positions where venous hæmorrhage is most to be feared, especially under the conditions just cited, are as follows —

1 The splenic pedicle
2 The renal pedicle
3 The neck, particularly
   (*a*) the root of the neck,
   (*b*) near the bulb of the jugular.
4 Deep in the pelvis

The following principles may prove helpful —

THE CONTROL OF VENOUS HÆMORRHAGE

Venous hæmorrhage can usually be controlled by digital pressure Once the bleeding is controlled with the fingers do not be in haste to apply hæmostats, but rather wait awhile until the patient is not straining, and if possible utilize every means to obtain adequate exposure If a hæmostat can be applied satisfactorily to the bleeding point, but owing to inaccessibility it is difficult to place the ligature, consider the advisability of trusting treatment the surgeon has to rely on intelligent guesswork. Such objective signs as redness, pitting on pressure and tenderness are seldom present except when the veins concerned are superficial. When the affected vein lies beneath the deep fascia the infective process continues for days or even weeks without any of the signs that the clinician is wont to expect. Probably comparison of the two limbs will reveal some swelling on the affected side though a tape measure may be needed to detect it.

The infection results in thrombosis which extends mainly in the direction of the blood stream, though, as John Hunter noticed, it spreads also against the stream and along tributary veins. This clotting extends rapidly along

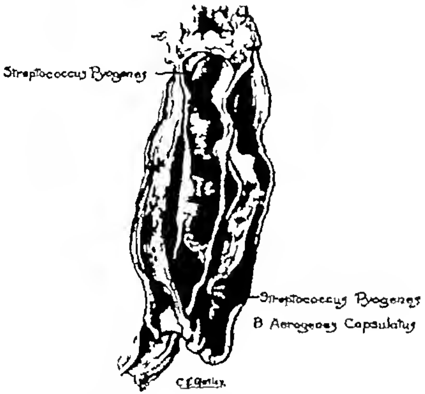

Fig. 200

Illustrating septic arteritis and septic phlebitis. The structures were removed by operation from an amputation stump and the patient recovered. A streptococcus was obtained from the artery, while both streptococci and B. aerogenes were grown from the vein. (*Reproduced by kind permission of the R.C.S. England, from the writer's Jacksonian Prize Essay* 1920.)

veins which have few or no large tributaries, such as the internal saphena or the cephalic; it progresses more slowly when the vein has many tributaries, as in the deep and common femoral veins. In every case seen by the writer at operation or necropsy the upper end of the massive clot has coincided with the junction of two veins. Unhappily this does not mean that the septic process has been arrested at this level, for though the gross clotting may not extend farther, yet when a vein is divided above the obvious clot an examination of its lining often shows fine mural thrombosis and bacteriological examination usually reveals the presence of streptococci at this level.

which bleeding has taken place. An anæsthetic has been given, the wound has been opened up, and the surgeon is clearing out blood clot, when there is a sudden profuse gush of dark blood which he stops with his finger, and which he finds to issue from a perforation at the junction of the internal jugular and subclavian veins. To stem the blood and inspect the vascular wound he may be tempted to secure the two tributary veins but the moment he cuts off the supply of blood from the periphery air will be drawn into the innominate vein with each inspiratory movement, and it is not so easy to stop this entry of air as it is to prevent the egress of blood. The proper course is to secure first the vessel on the proximal side of the lesion. So long as blood is not prevented by distal pressure from reaching the wound in the vein, little or no air will be sucked in. The fact of air entry can be recognized by the hissing sound that accompanies the process.

FIG. 205

Air embolus, the danger area

A certain amount of air can be drawn into a vein without causing any symptoms; if more gains entry, the patient will become dyspnœic and cyanosed, and if the influx be not speedily checked he will die.

Remedial treatment is not very satisfactory. The circulation becomes embarrassed by an accumulation of air (*a*) in the right auricle and (*b*) in the small blood vessels of the lung. To empty it of air aspiration of the right auricle by puncture with an exploring needle or by catheterization through the jugular vein have been suggested. Cardiac massage through a laparotomy wound has been recommended in addition. Concerning the blockage of the pulmonary vessels Curtillet and Curtillet have shown by experiments on animals that air entering the pulmonary arteries becomes fragmented into minute bubbles which are arrested in the smallest arterioles of the lung. In this situation they rather rapidly undergo complete absorption. Recognizing this spontaneous tendency to a cure it would seem advisable to persevere with artificial respiration if and when the patient's own respiratory efforts become inadequate.

SEPTIC PHLEBITIS

Unlike the arteries, the veins are prone to infection. At the Base Hospitals in France during the 1914-18 war, septic phlebitis appeared to be the chief cause of death following gunshot wounds of the limbs, being found in more than half the fatal cases under the writer's care in which careful examination was made. The streptococcus pyogenes was the usual causative agent.

In the early stages there may be little or no local evidence of the condition, and the diagnosis has to be based on the existence of a remittent temperature with the absence of a local collection of pus. Unfortunately this is the favourable period for remedial treatment; by the time the condition has become manifest locally the patient may be beyond help. For successful

CHAPTER XXV

RECENT ADVANCES AND EXPERIMENTAL WORK IN CONSERVATIVE VASCULAR SURGERY

THE USE OF HEPARIN IN VASCULAR SURGERY

HEPARIN is a natural anticoagulant of the blood originally procured from the liver but later it has been shown to occur in many other tissues—notably the lungs—from which it is now largely extracted

The purification of heparin has resulted in an increased interest in the surgery of blood vessels In particular it has opened up new possibilities in arterial suture venous grafting and embolectomy

Heparin was first isolated in America at the time of the 1914 18 war and it is now available in a non toxic form suitable for intravenous injection

In addition to being an anticoagulant recent research indicates that while it is incapable of removing clot already formed it will prevent thrombosis Anaphylaxis is unlikely to follow its administration and the increase in the clotting time depends on the dose given there being no negative phase

Indications in the surgery of the blood vessels—Many conservative operations on the blood vessels have been marred by functional failure a physiological fault rather than an operative imperfection This is due to thrombus formation occurring on the damaged intima and spreading peripherally to affect the collateral vessels The anticoagulant and thrombus preventing properties of heparin promise in a large measure to obviate this bugbear of vascular surgery

Modes of administration—1 GENERAL HEPARINIZATION is produced by a continuous intravenous injection so as to increase the clotting time of the blood in all parts of the body It is the method generally favoured.

2 INTERMITTENT INTRAVENOUS INJECTION is particularly recommended in cases of urgency

3 REGIONAL HEPARINIZATION is the injection of sufficient heparin into an artery proximal to the suture line so as to affect the clotting time in one limb but not to alter the clotting time of the whole blood stream

Technique of administration—When heparin has to be administered it is desirable to make provision for the following measures —

1 Arrangements must be made for an estimation of the base line of the patient s clotting time Facilities for determining the clotting time during the process of administration are also desirable

2 An intravenous drip apparatus must be in readiness for continuous administration into a vein is the method most frequently employed (general heparinization)

Mode of entry of infection—Perhaps the commonest origin of septic phlebitis is infected bone but apart from osteomyelitis it has been seen in septic amputation stumps, where the ligature may have caused injury to the vein wall, and in wounds containing foreign bodies which may have directly opened a vein or caused a pressure necrosis of its wall

Appearance of infected vein—In the early stages the vein merely contains dirty-looking clot (Fig 206) In advanced cases the wall of the vein near the source of infection is yellowish opaque and lustreless, and surrounded by plastic œdema The vein at this level may be empty the collapsed wall and the surrounding leucocytic exudation sometimes render it difficult to recognize Followed in a proximal direction the vein will be found to contain partly decolourized clot and further still, it contains healthy-looking clot If the vein be examined at a point much nearer the heart than the thrombus its wall, though appearing normal, may yet be infected

TREATMENT

Prophylactic—Obviously the prevention of septic phlebitis is part of the general prophylactic treatment of infected wounds and does not demand special consideration here

Remedial—Treatment of the primary focus of infection will be required especially in the presence of osteomyelitis chemotherapy is indicated Beyond such measures the prevention of pulmonary sepsis by infected emboli must be considered Immobilization may help in this Ligation of the vein above the clot with drainage of the infected segment is indicated In the 1914-18 war such treatment was followed by occasional success only, no doubt because usually it was undertaken too late On the other hand, in some instances amelioration was immediate and sustained Because infection extends centripetally to regions where the vein still appears normal, ligation and division should be done whenever possible at a point much nearer the heart than the obviously infected part of the vessel It is sometimes impossible to be certain which vein is infected consequently the wrong one may be tied Here is an example A soldier had a gunshot wound of the thigh and septic phlebitis was diagnosed Not knowing which vein to secure, I tied the superficial femoral This brought no improvement and the patient died At the necropsy the profunda femoris was found to be the seat of septic phlebitis which meanwhile had extended into the common femoral vein

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A SUGGESTED METHOD OF PREVENTING ACUTE FAILURE OF THE CIRCULATION AFTER INJURY TO LARGE BLOOD VESSELS

During the 1914-18 war many limbs and lives were lost following injuries to large blood vessels It is possible that a proportion of these would have been saved if they could have been admitted to a fully equipped hospital within a short space of time It seemed attractive therefore to investigate the possibility of providing a temporary expedient for dealing with wounds of large arteries which would suffice for even a few hours If by a simple method adequate circulation could be maintained for a few hours until the patient could be transported to a hospital with better operating facilities a permanent repair of the injured vessel or bridging of a gap by a venous graft might be carried out or the collateral circulation become established

In the past Tuffier's tubes have been employed for this purpose but without success within a matter of hours the tube and the adjacent segments of the blood vessel became obstructed by clotted blood It was hoped therefore that by using heparin to prevent plugging of such tubes and vessels better results would be obtained

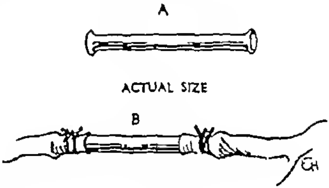

Fig 207

Experiments on dogs were undertaken A glass and vitallium cannula of a suitable size to fit the artery (Fig 207 A) was inserted between the cut ends of the common carotid The cut ends of the artery were secured behind the flanges by means of linen ligatures (Fig 207 B) Without the use of heparin these tubes became plugged on an average within twenty minutes following the re-establishment of circulation through this cannula When, however a satisfactory continuous intravenous injection of heparin was given to raise the clotting time of the animal from the normal of two to thirteen minutes or more the cannula remained patent in all experiments To obtain this effect about 53 units of heparin per kilogram per hour were necessary

With excessive dosage of heparin there was apt to be oozing from the operative field but when the clotting time was kept at about fifteen minutes there was little or no oozing If the experiments on thrombin continue to show that this substance will prevent oozing from exposed surfaces thrombin might be used with advantage as a surface application on surgical wounds in patients who are receiving heparin

I have had no opportunity to use this method on human beings and since the dosage required to heparinize an animal differs from that required to produce the same effect in a patient it is difficult to predict accurately what this dosage should be From our experience with heparin in surgical patients it is suggested that between 15 and 20 units per kilogram per hour

3 Those in attendance must be vigilant concerning the possibility of post-operative bleeding after this anticoagulant has been injected, and be prepared accordingly

Dosage and preparations—As different standards have been employed and as various preparations are on the market, it is imperative that all doses should be checked before use.

1 General heparinization to prevent thrombosis—Employing the crystalline barium salt of Charles and Scott, Murray and Best use the ordinary intravenous drip, and sufficient heparin is added to the salt solution *to increase the clotting time to about fifteen minutes* Usually heparin is added in the proportion of 10 units of heparin to 1 c c of saline In the average patient this should be run in at about 25 to 30 drops per minute The rate, however, is adjusted according to the effect on the clotting time, and this is estimated every few hours until the correct rate of injection can be determined

In order to obviate oozing from the wound, heparin is not administered until from four to twenty-four hours after the operation, it is continued until it appears that further thrombosis is unlikely, *e g* for a period of ten days or even longer

"*Liquemin*" is the heparin preparation supplied by Roche Products Ltd One cubic centimetre contains 4 mg of pure heparin powder and corresponds to 2,000 anticoagulant units (A C U) Normal saline containing 10 mg "Liquemin" per 100 c c is run into a vein at such a rate as to maintain the clotting time at about the customary fifteen minutes On an average 25 to 30 drops of saline a minute are required continued if necessary for fourteen days

2 Intermittent injection to prevent failure of the circulation after insertion of Tuffier's tube—From the animal experiments quoted below, Murray and Janes consider that intermittent intravenous injections of heparin in doses of 1,500 units *q h* would suffice for a patient of average weight

3 Intermittent injections to prevent thrombosis—Among the other preparations procurable at present in England is heparin B D H, the activity of which is expressed in Toronto units In man, 100 Toronto units of heparin per kilogram body-weight, when given intravenously, raise the coagulation time to approximately forty minutes

In the treatment of thrombosis the dose of heparin B D H is 7,500 to 15,000 Toronto units administered intravenously in the form of a sterile solution containing 5,000 units per cubic centimetre The dose is repeated four to five times a day until the condition of the patient indicates that it may be reduced with safety The first injection is given four hours after the completion of the operation

4 Local heparinization—After embolectomy or arterial suture it is recommended that a dose of 5 c c of "Liquemin" in 20 c c of normal saline be injected into the lumen of the vessel After suturing a solution of heparin is run drop by drop along the incision In four to twenty-four hours intravenous injection is commenced

CHAPTER XXVI

SECONDARY HÆMORRHAGE

This chapter is based on the experience of the late H. F. Wolfenden and the writer in a base hospital of 1,300 beds during the years 1916-18. Full statistical records are not now available, but some figures of the case incidence can be given. About 3,000 patients with wounds involving long bones were treated in each twelve months; of these, in the first year 14 per cent. developed secondary hæmorrhage and in the second year 9 per cent. The reduction in the incidence of secondary hæmorrhage during the latter period reflected the improved arrangements for adequate early excision of wounds, which became operative at the clearing station in 1917. With regard to the nature of the wound, in 116 cases of secondary hæmorrhage 68 per cent. were associated with compound fractures, 12 per cent. with wounds of the jaw and neck, the remainder being classed as miscellaneous.

Varieties.—Secondary hæmorrhage is usually arterial. Occasionally troublesome bleeding arises from a vein or venous plexus. Three types of secondary hæmorrhage are often described: (i) arterial, (ii) venous, (iii) parenchymatous.

Regarding the last, no one can deny that considerable bleeding can and does occur from traumatized granulation tissue, but in cases where such bleeding is sufficiently profuse to require operative intervention an actual bleeding artery is found so often as to make one doubt whether it is even justifiable to diagnose parenchymatous secondary hæmorrhage.

Etiology.—The time of onset of secondary hæmorrhage coincides with the normal time of disintegration of catgut. This may have a bearing in cases where ligatures have been applied for primary hæmorrhage. Sir George Makins believed that an incomplete primary lesion of a blood vessel pre-existed in every case of secondary hæmorrhage (Fig. 208). Other authorities hold that secondary hæmorrhage is the result of invasion of the arterial wall and its primary clot by proteolytic ferments evolved by the interaction between invading organisms and the

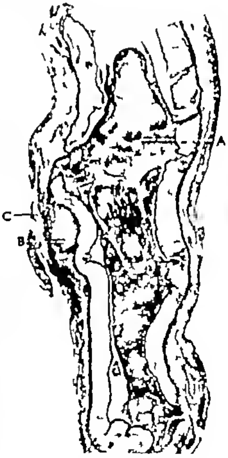

FIG. 208

Longitudinal section through a femoral artery from which secondary hæmorrhage took place.

A. Thrombus in the artery. B. Extravasation of blood into the adventitia. C. Point at which the arterial wall had given way.

(Sir George Makins.)

should be adequate. Under the conditions in which this procedure might be useful, a continuous intravenous injection would be impracticable, so intermittent intravenous injections would have to be used. A dose of 1,500 units given intravenously every four hours should suffice in a patient of average weight.

As a result of these experiments[1] I suggest that it would be possible to insert a glass or other cannula of suitable size into a large, torn artery soon after the accident. With appropriate doses of heparin the artery might be kept patent until the patient is admitted into hospital, where repair of the vessel could be attempted. Cannulization of a major artery is not difficult, and could be undertaken at an advanced dressing station. Care must be taken to damage as little as possible the adjacent healthy segment of the artery. By employing these expedients it seems possible that some of the disastrous effects of acute failure of the circulation in the extremities and the neck might be obviated.

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[1] I wish to acknowledge the assistance of Dr. J. M. Janes in doing this experimental work.

hæmorrhage Again there is no reason why this apparatus should not form a part of the equipment of every surgical ward and if it is available it can be applied over the pad (Fig 210) instead of the Martin s bandage

Other emergency measures—1 There are sites where it is difficult or impossible to obtain pressure by the means just described Such situations are the buttock the root of the neck and the abdomen Arrest of hæmorrhage in these difficult regions can often be effected by introducing the bag of a sphygmomanometer over the pad and in the bandage and inflating it sufficiently (Fig 210)

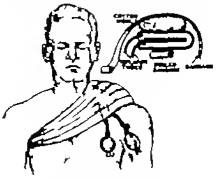

Fig 210
Method of using sphygmomanometer bag for hæmorrhage from the root of the neck

2 In extremely urgent cases disastrous torrential hæmorrhage can be checked by packing the wound with gauze and stitching the skin tightly over the packing The first occasion on which I used this method was in August 1914 in a case of hæmorrhage from the common carotid The expedient in this instance proved successful

General treatment—It is of cardinal importance that treatment for hæmorrhage be instituted as soon as possible after the bleeding has been temporarily controlled No time should be lost in making arrangements for transfusion of whole blood or plasma if the loss of blood has been great the former is indicated In addition to morphia a hypodermic injection of ergotoxin is helpful in view of its inhibiting action upon the sympathetic nervous system

Light gas and oxygen anæsthesia should be begun early to allay restlessness and relieve the patient s mind

Operative treatment—Four questions present themselves for decision —

1 Where to ligate ? 3 When to pack ?
2 What to ligate ? 4 Which (if any) local styptic should be used ?

1 Where to ligate—The question of the advisability of proximal ligature of the main vessel has been the subject of much discussion With the sole exception noted below it can be stated categorically that proximal ligature of an arterial trunk through a fresh incision is inadmissible in any case of secondary hæmorrhage Two very good reasons support this principle Firstly in spite of meticulous care the new wound very frequently becomes infected Secondly only too often it transpires that the hæmorrhage was not from the main arterial trunk but from a branch thereof and the hæmorrhage recurs It is only after such humiliations that it comes to be fully realized how futile and mischievous a proximal ligature can be

The bleeding point must be sought and controlled within the area of the wound The main exception[1] is secondary hæmorrhage from the gluteal arteries which is comparatively common in wounds of the buttock While the exposure of Fiolle and Delmas (p 103) has done much to surmount the difficulties of securing the bleeding vessels within the area of the wound

[1] Professor Ernest Finch writes Ligation of the brachial artery is regarded satisfactory in cases of secondary hæmorrhage from the palm

local tissues It has been shown in these cases that the pus from the wound is acid in character with a pH value of about 6 5, and that it has a low cell content It is probable that chronic septicæmia of low virulence is present in the majority of these patients True, blood cultures are not often positive, but studies of the leucocyte count seem to substantiate the hypothesis (H A Cookson)

No vessel is exempt, but secondary hæmorrhage occurs more frequently in certain regions In the case of the limbs these are the calf, thigh, buttock, axilla and palm Possibly a determining factor is the degree of anatomical mobility of the artery For example, secondary hæmorrhage from the femoral artery is rare in the region of Scarpa's triangle, but common in Hunter's canal

Premonitory signs—Secondary hæmorrhage occurs most frequently in suppurating wounds between ten and sixteen days after receipt of the injury The "red signal" is a small initial hæmorrhage occurring in a wound which, up to that time has discharged pus This warning occurs in more than half the total cases and constitutes an inexorable indication for exploration of the wound The nursing staff must be instructed to report at once even a slight hæmorrhage or the discharge of small clots Often, if this warning is disregarded, within a few hours there is a greater maybe a life-endangering, loss

Curiously, the constitutional reaction to the premonitory leak is sometimes out of all proportion to the amount of blood lost Suddenly there are the signs of severe shock, including pallor, rapid pulse and restlessness Leriche states that this syndrome is due to general peripheral vasoconstriction by reflex action

TREATMENT

Immediate treatment—Unfortunately digital pressure is rarely effective in this type of hæmorrhage Except in the direst emergency, the use of an ordinary proximal tourniquet should be eschewed This statement, which is at variance with the usual teaching is not made without good reason Unquestionably the application of a tourniquet imperils the viability of a limb When the patient is debilitated a tourniquet is even more likely to devitalize tissues These patients are always gravely debilitated, and therefore the fate of the distal part of the injured limb is precarious

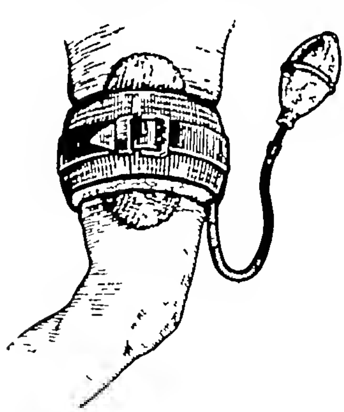

Fig 209
A pneumatic tourniquet applied directly over a pad of gauze over the wound is the best immediate treatment of secondary hæmorrhage

A far better method than the application of an ordinary tourniquet is to place a large pad of gauze or wool over the site of the hæmorrhage and to apply a Martin's rubber bandage sufficiently firmly over it In the absence of a rubber bandage flexible adhesive plaster could be used, but there is no reason why a rubber bandage should not be provided in every ward

The pneumatic tourniquet (Fig 209), which is used but little in Britain, is the least traumatic and the most effective instrument for arresting urgent

3 WHEN TO PACK—To find the bleeding vessel and to be able to deal with it as indicated above is a source of real satisfaction Unfortunately there is a number of cases probably the majority where for various reasons the actual bleeding vessel cannot be identified. Prominent amongst the causes of this disappointment is the fall in blood pressure a comparatively small artery ceases to bleed. If on opening up the wound the actual bleeding point cannot be identified quickly in the suppurating tissues no time should be lost in making the decision to rely on packing Gauze packing should be inserted systematically and evenly and over this a pneumatic tourniquet or a rubber bandage is applied Usually within forty-eight hours the packing is removed in the theatre by the surgeon himself and in many instances its removal is uneventful In other cases an opportunity to identify the bleeding point is presented and in still others recourse must again be made to packing In relevant cases the advisability of amputation will arise

4 WHICH (IF ANY) LOCAL STYPTIC SHOULD BE USED—Numerous styptics have been advocated for use in conjunction with packing The best and perhaps the only one of value[1] is a 30 per cent solution of sodium citrate This solution was used widely in 1917 18 and it displaced all other forms of styptic in the practice of a large number of experienced surgeons Sodium citrate being strongly alkaline has the further virtue of neutralizing the acidity of the pus in the wound

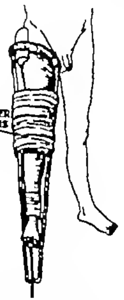

FIG 213
Immobilization of the part after the control of secondary hæmorrhage must permit hourly inspection of the region distal to the hæmorrhage

Ancillary measures—The most effective single agent in limiting the spread of wound infection is immobilization of the part and it is especially advisable that this principle be observed in dealing with secondary hæmorrhage The plaster cast which is now playing such an important rôle in the treatment of infected wounds is not suitable for use in these cases The distal segment of the limb must be available for frequent inspection to ensure that its viability is maintained For the lower limb there is no better method than the Thomas splint with moderate extension, combined with a few turns of plaster bandage over the limb and the splint in the region of the wound (Fig 213) The foot and as much of the leg as practicable should be exposed to view and inspected hourly The limb should not be elevated.

As emphasized by Professor Learmonth in Chapter XXIII we must refrain from our natural impulse to apply heat to the threatened member, and attempt to secure reflex dilatation by immersing the sound extremities in water at about 110 F

[1] Pure thrombin has recently been isolated and will probably be available as a commercial product before long —Ed.

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there are occasions when a friable vessel deep in the sciatic notch makes this procedure insuperably difficult In such cases it is justifiable to tie the internal iliac artery or its posterior branch If the condition of the patient permits, it is best to perform this operation by the extraperitoneal route, stripping the muscles from the inner aspect of the iliac bone down to the notch and there tying the vessel Suppuration on the inner aspect of the bone is not uncommonly found and can be drained effectively only by this route Proximal ligature of the external carotid for hæmorrhage from the internal maxillary artery is often recommended, I think it is better surgical practice to avoid this by packing the wound firmly, and stitching the skin over it

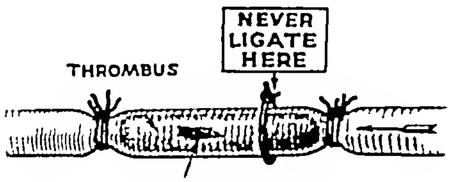

FIG 211

In secondary hæmorrhage, if clot is present in the artery, ligate above and below as shown When possible excise segment enclosed between the ligatures

2 WHAT TO LIGATE—Let us examine and digest Sir George Makin's dictum based on the observation of many hundreds of cases "If the arterial coats are not seriously damaged and the wound likely to respond to treatment an expectant attitude (*i e*, packing) should be assumed, *provided the vessel is pervious* but if the artery is thrombosed, ligatures should be placed above and below the clot and the vessel divided" It should be noted particularly that ligation should never be made in the portion of the vessel occupied by the clot The reason for this is that a "pencil slough" may form and be discharged later, with the inevitable result of renewed catastrophic hæmorrhage When it is practicable excision of the thrombosed length of the vessel is the best practice (Figs 211 and 212) In addition to removing the infected clot, this plan has the further advantage of interrupting stimuli from sympathetic nerves and thus preventing vasoconstriction in the distal part of the limb

FIG 212

Thrombosed segment of the superficial artery removed for secondary hæmorrhage which occurred from the two points which can be seen as dark areas (*Sir George Makins*)

There is another important question to be considered under this heading Some doubt has arisen as to the advisability of ligating the vein at the same time as the artery By coincident ligation of the vein a considerable amount of fluid blood is retained in the vessels of the distal part of the limb, sufficient to preserve the permeability of the vessels pending the development of a collateral circulation By preserving the nutrition of the limb during a critical period, there is every reason to believe that the practice mitigates against gangrene, and in my view it should never be omitted from the operative procedure

Ligature material—The nature of the ligature material is of importance In general, catgut should be avoided Fine silk thread has the disadvantage of damaging the intima and often cutting through the vessel No 8 gauge Chinese silk or narrow tape proved to be the most satisfactory material The ends are left long and protrude from the wound, at the end of fourteen days they are gently withdrawn

Surgical pathology—During the formation of a traumatic aneurysm in the way just detailed certain anatomical changes important to the surgeon occur Various tissues including nerve trunks (Fig 217) lying near the wounded vessel become embodied in the wall of the aneurysmal sac Thus anatomical details in the region of the aneurysm are liable to be obscured Another hazard in operating upon a newly formed traumatic aneurysm is matting of the tissues concerned including the wounded artery It will be realized that the whole region is plastered with fibrin and scar tissue

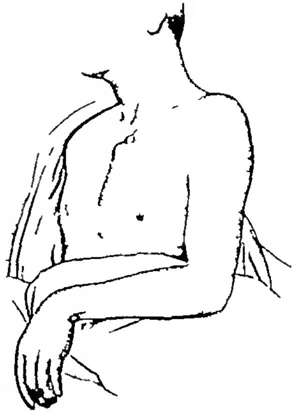

Fig 217

Traumatic aneurysm of the second portion of the left axillary artery The bullet entered the outer part of the deltoid region, and was retained. The wrist-drop due to the involvement of the brachial plexus should be noted. (*British Journal of Surgery*)

Even freshly formed clot forms an effective barrier to the passage of blood the organized sac of an established traumatic aneurysm is a still more effective barrier and although in response to the pressure of arterial blood the sac of an arterial hæmatoma may gradually expand it is not likely to be the seat of hæmorrhage unless the clot becomes disintegrated by sepsis The weak place is the line of contact between the clot and the margin of the wound in the arterial wall (Makins) (See Fig 214)

Diagnosis—In the early stages an arterial hæmatoma does not necessarily exhibit expansile pulsation At this time the hardness of the hæmatoma apart from other evidence may lead us to suspect the presence of an arterial wound It is highly important to ascertain whether or not the hæmatoma is increasing in size (Fig 218) marking its outline on the skin and the use of a tape measure will settle this point in good time Another important clinical observation which should be recorded is the effect of digital pressure at or near the site of arterial injury If such pressure does not obliterate the distal pulse it is unlikely that ischæmia or gangrene will occur and other factors

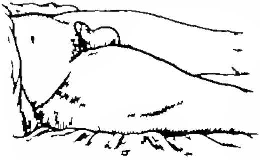

Fig 218

Diffuse arterial hæmatoma. (*After Sencert.*)

CHAPTER XXVII

ARTERIAL HÆMATOMATA AND TRAUMATIC ANEURYSM

WHEN a wounded artery does not communicate freely with the exterior, with a body cavity, or with a vein, it bleeds into the tissues The escaping blood fills the space about the artery and vein within their common sheath, and if this is not intact it infiltrates in other directions When the wound in the artery is small and the surrounding tissues are comparatively unyielding, for example a puncture of the femoral artery in Hunter's canal, *a circumscribed arterial hæmatoma* (Fig 214) may result Such a limited effusion causes little hindrance to the collateral circulation

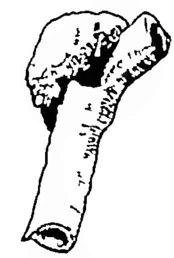

FIG 214

A circumscribed arterial hæmatoma resulting from a wound of the right common carotid artery

When the bleeding is not closely restricted a *diffuse arterial hæmatoma* (Fig 215) forms, in this event the effusion of blood may extend far and obstruct the collateral circulation, thereby causing ischæmia or gangrene

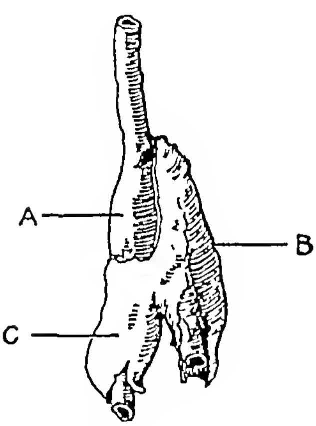

FIG 215

Diffuse arterial hæmatoma which gave rise to secondary hæmorrhage on the eighth day

A, Bifurcation of brachial artery B, Vein which is thrombosed C, Clot partially within the common vascular sheath

Development of a traumatic aneurysm—Whether the initial hæmatoma is circumscribed or diffuse, its further extension is checked by a barrier of clot Unless some untoward complication ensues, a time is reached when the blood ejected through the hole in the artery with each pulse is confined to a cavity lined by blood clot (Fig 216) Still later the wall of clot becomes more resistant by the condensation of fibrin, by the ingrowth of blood vessels and the development of a fibrous stroma Eventually this cavity becomes lined with endothelium spreading to it from the artery When this process has ended, the metamorphosis of an arterial hæmatoma into a traumatic aneurysm is complete

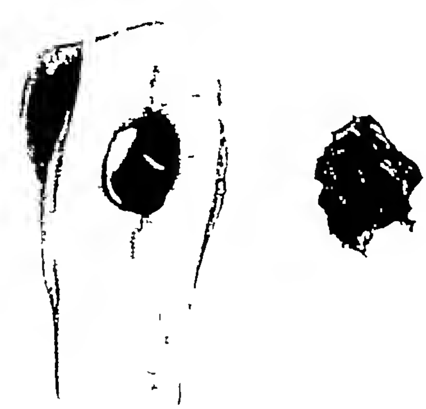

FIG 216

Two and a half inches of the common carotid excised during an early stage of the formation of a traumatic aneurysm The thin-walled aneurysmal sac was placed behind the artery The missile was removed at the same time (*R J Swan, British Journal of Surgery*) in these traumatic cases is often very difficult and perhaps disastrous The especial difficulties are due to the incorporation in the sac wall of neighbouring structures and the multitude of tributaries opening into the sac The latter factor must also be contended with when the aneurysm is treated by ligation To occlude these tributaries is essential They can be detected by opening the aneurysmal sac and loosening the tourniquet

In wounds of the great arterial trunks at the root of the neck distal ligature alone has occasionally brought about a cure and as the operation may be easy as well as effective while proximal ligation in this situation would be difficult and perhaps hazardous it has a distinct place in surgery

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being equal, this would strengthen the clinician's hand in advising delay, in fact, so long as a distal pulse can be felt there seems to be little immediate danger of ischæmia or gangrene. Later, when the hæmatoma has resolved, a pulsating swelling accompanied by a systolic bruit affords indisputable evidence of a traumatic aneurysm. The stethoscope is indispensable in dealing with arterial injuries, and a bruit may be the only immediate evidence of a breach in the vessel wall for example when the carotid is injured. The bruit is apt to be conducted distally along the course of the injured blood vessel.

TREATMENT

Arterial hæmatomata—With immediate recognition and treatment the formation of an aneurysm and other more serious complications can be forestalled.

Cases diagnosed within eighteen hours of wounding—The treatment differs not at all from that of wounded arteries, which has been considered already (Chapters XXIII and XXV). A diffuse arterial hæmatoma in which gangrene is threatened is the indication *par excellence* for the use of a temporary cannula and heparinization (p. 239). The presence of gross contamination debars attempts to preserve or restore the circulation of a limb. Gross contamination plus signs of impending gangrene usually indicate that amputation is the wisest course.

Later cases—When an arterial hæmatoma has been discovered too late for primary wound treatment, in carefully selected cases it is wise to defer operation so as to allow time for an efficient collateral circulation to develop. Experience shows that operations during the intermediate stage of a traumatic aneurysm are not so easy or satisfactory as those done at an earlier or later period. During the intermediate stage the structural details are obscured by fibrin, inflammation and scarring, and the vessel walls are so thickened and friable that they cannot be sutured. After an interval of two or three months these untoward factors will be lessened, and the longer surgical intervention is delayed, within reasonable limits, the easier it will be and the less will be the chances of causing ischæmia and gangrene. In many cases such delay is impossible because of secondary hæmorrhage, diffusion of the hæmatoma, a rapid increase in the size of a circumscribed hæmatoma, or some other complication, notably the presence of sepsis and foreign bodies. In such circumstances operation must be hurried forward. When the necessity for operation is established it is essential for the surgeon to remember three principles:—

1. Exposure of the wounded artery must be adequate.
2. The wounded vessel must be ligated above and below the bleeding point and either divided or, preferably, the damaged portion excised.
3. If the wound is infected it must be left quite open.

Traumatic aneurysms—The treatment of an established traumatic aneurysm follows the principles of the treatment of aneurysm in general. Excision of the aneurysm is sometimes recommended, but its performance arterial hæmatoma thus produced unlike that following a perforation of the artery alone remains soft and shows little or no tendency to enlarge for the blood ejected from the artery can escape into the vein Owing to this relief of tension firm healing usually follows and secondary hæmorrhage seldom occurs

Diagnosis—EARLY SIGNS—*Anatomical relationships of the wound*—The situation of a wound especially when the sites of entry and exit are considered will often suggest at once that the track of the projectile is

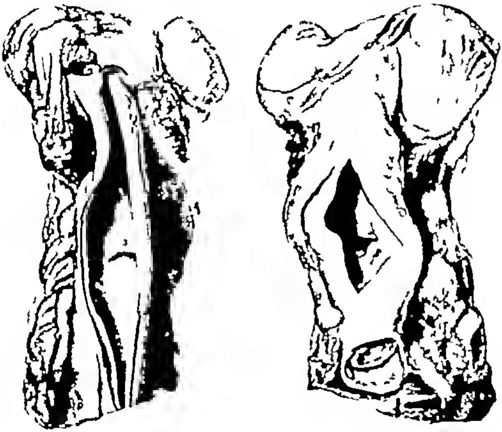

FIG. 220

An aneurysmal varix of the common carotid artery and internal jugular vein. The patient died on the seventh day from concurrent head injuries. The adhesion between the two vessels was immediate and complete (*Sir George Makins*)

dangerously near some artery So too will injury to nerves which lie near an artery For example if a wound of the neck is followed by paralysis of the cervical sympathetic one must suspect that the carotid artery may have been wounded.

Nervous phenomena—A common accompaniment of wounds which pass close to and perhaps involve the main blood vessels of the upper or lower extremity is a temporary paresis of the whole limb accompanied by numbness to the slighter forms of cutaneous stimuli The distribution of the sensory defect is of the glove or stocking type and it usually retains this distribution during recovery the proximal areas being the first

CHAPTER XXVIII

ARTERIO-VENOUS ANEURYSMS FOLLOWING GUNSHOT WOUNDS

TRAUMATIC arterio-venous fistulæ are of various kinds (Fig 219)

ANEURYSMAL VARIX

With aneurysmal varix there is no aneurysmal sac (Fig 219, A B, C) The condition is caused by a foreign body passing between an artery and its attendant vein lying in juxtaposition The wounds involve a small fraction only of the circumference of each vessel so that little retraction occurs.

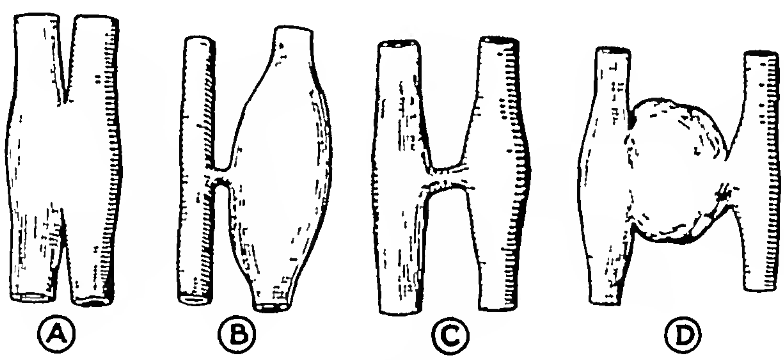

Fig 219

Varieties of arterio venous fistulæ

(A) Direct communication between artery and vein (B) Aneurysmal varix The vein is dilated evenly (C) Arterio-venous fistula united by a small fibrous canal (D) Varicose aneurysm

Blood escaping from the artery passes directly through the hole into the vein There is but little effusion of blood into the surrounding tissues, and no arterial hæmatoma is formed Owing to the absence of tension, firm healing ensues so as to produce a durable fistula between the vessels (Fig 220)

VARICOSE ANEURYSM

The feature which distinguishes this from aneurysmal varix is the presence of an aneurysmal sac (Fig 219, D) The condition may be caused in the same manner as an aneurysmal varix, except that the vascular breaches are larger Another method of production is by a projectile passing across an artery and a vein and wounding both at the same level In either case blood ejected from the artery does not escape entirely and at once by the vein, but leaks into the tissues, producing an arterial hæmatoma The contrast with this the left foot became gangrenous and amputation was necessary

Secondary hæmorrhage—In contradistinction to arterial hæmatoma secondary hæmorrhage from an arterio venous aneurysm is so unusual as not to warrant serious consideration

DEFERRED SEQUELS—*Wasting of the affected limb*—As might be antici pated the reduced arterial supply due to an arterio venous fistula causes some loss of muscular efficiency in the affected limb

Cardiac disturbances—In the presence of an arterio venous fistula a certain amount of blood escapes into the vein with each pulse and so wastes an equivalent proportion of the heart s effort to maintain the arterial blood pressure at a proper level This may be the cause of the cardiac disturbances which arterio venous aneurysms are apt to produce with the lapse of time

Intracranial arterio-venous aneurysm—Occasionally as the result of cranial injury an arterio-venous fistula is formed in con nection with the cavernous sinus The chief signs of the vascular lesion in these cases are (1) pulsating exophthalmos (Fig 221) (2) a systolic bruit heard most loudly at the temple of the affected side and perhaps audible over the entire cranium (3) if the patient is conscious a throb bing headache In addition there may be evidence of cerebral injury and of a fracture of the skull Early operation is required in these cases which thus differ from the arterio-venous aneurysms previously considered

FIG 221
Intracranial arterio-venous aneurysm
(*British Journal of Surgery*)

TREATMENT

The perils of ischæmia gangrene and secondary hæmorrhage are not to be expected with arterio venous aneurysms which therefore do not demand early operative treatment In view of the relief of tension by the escape of blood into the vein the wall of the fibrinous sac can be relied on as an effective barrier to the further infiltration of arterial blood into the tissues In the early stages however this primary aneurysmal sac of laminated clot is not firmly fixed to the vessels and may be readily separated from them This is the weak part of all arterial hæmatomata (Fig 222) Against detachment of the sac immobilization is the remedy and if no secondary hæmorrhage or continued infiltration of the surrounding tissues with blood takes place any question of operation on account and the fingers or toes the last to recover The cause of these nervous phenomena has not been identified, the writer could not trace them to the use of tourniquets, and they are perhaps attributable to injury of sympathetic nerves. This condition is called arterial stupor

Thrill—One of the most characteristic features of an arterio-venous aneurysm, and particularly of an aneurysmal varix, is a palpable thrill In twelve cases of arterio-venous aneurysm of which the writer has kept records, a thrill was noted in seven, and it may have been present in others[1]

Vascular bruits which can be heard with the stethoscope over the injured part may offer unmistakable evidence of an arterio-venous communication

Usually there is a rather loud systolic bruit, followed by a softer diastolic hum which may require quiet surroundings and close attention for its perception In the presence of a thrill, murmurs may be widely conducted In a case of arterio venous fistula of the common femoral vessels accompanied by a thrill, the murmurs were audible with the stethoscope placed on the dorsum of the foot

When the presence or absence of vascular bruits is being investigated with the stethoscope, it is necessary to bear in mind that they may be caused by the pressure of a foreign body or fragment of bone on an uninjured artery The stethoscope itself when applied too firmly in places where there is a hard background may cause a systolic murmur

The bruit, even when the carotid is involved, may not disturb the patient, and in some instances it remains unnoticed by him Usually, however, the constant noise causes much distress A patient of mine likened the sound to that of a hive of bees

Presence of a pulsating swelling—As mentioned above, an aneurysmal sac is a characteristic feature of a varicose aneurysm At the clinical examination of recent wounds such a sac is not usually recognizable

Pulsation in the veins concerned with an arterio-venous fistula is of little if any value as an early diagnostic sign, it was not recorded in any one of the writer's case notes Probably it would have been noticeable at later stages

Changes in the distal pulse—Obliteration of the distal pulse is not a common complication of arterio-venous aneurysm In none of my twelve cases was the pulse distal to the lesion rendered impalpable, though in three it could only just be felt

A deficient circulation of blood accompanies some arterio-venous aneurysms, the results include general weakness of the limb, early fatigue on exertion, and perhaps swelling and pain when the limb is dependent—symptoms which resemble those following closure of the main venous channels A special and noteworthy feature is the speed with which the swelling disappears after elevation of the affected part

Ischæmia and gangrene do not appear as frequent sequels to the formation of arterio-venous fistulæ

An example of the relative dangers of an arterial wound and an arterio-venous fistula is afforded by the following case A rifle bullet had traversed both thighs, wounding the right and left common femoral arteries On the right a varicose aneurysm resulted, on the left there was an arterial hæmatoma or aneurysm In the right leg there were no grave sequelæ demanding operation before the patient's departure to England In

[1] It must be made clear that numerical figures given in this article are of no value as statistics No attempt was made to keep records of every case that was seen The fragmentary notes available largely represent cases having some particular interest, either because they were unusual or because they conveyed some lesson

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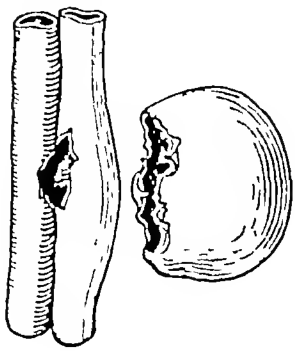

FIG 222

Arterio venous aneurysm with sac detached In the early stages the sac formed of laminated clot can be separated as shown

When endeavouring before operation to estimate the effects of arterial ligation in these cases, it is well to realize that the absence of a distal pulse during digital pressure over the vascular injury has not the same serious significance as with arterial hæmatomata

Operative treatment—Certain measures used for the cure of arterial aneurysms are inappropriate for arterio-venous aneurysms

Distal ligature of the artery is absolutely barred it would compel more arterial blood than before to enter the vein *Proximal ligature of the artery* alone is also barred By blocking the main arterial channel it leaves open a short circuit into the vein by which much of the collateral blood supply to the limb would be lost, and thus definitely favours the onset of gangrene *Proximal ligature of the vein* alone gives temporary relief, but is futile, for minor venous channels enlarge to take its place

REPAIR OF THE FISTULA—This operation, associated with the names of Matas and Bickham, is the ideal, but it is available only in early or deferred cases During the intermediate stage arterial sutures can seldom be used effectively, for reasons already stated The method consists in opening the vein of an aneurysmal varix or the sac of a varicose aneurysm and closing the arterial fistula by suture The segment of the vein which is involved and the aneurysmal sac are then obliterated If the original wound involved only a small part of the circumference of the arterial wall there will be a single opening to be sutured in the artery, and if the operation is successful the circulation through the vessel will continue If a large part of the circumference was cut across, retraction of the vessel wall will have caused the proximal and distal ends of the artery to appear as two separate openings into the aneurysmal sac, and then closure will completely occlude the arterial channel In early cases the sewing of the hole in the artery must be done so as to bring intima into contact with intima along the suture line to avoid subsequent thrombosis In late cases the intima, having formed a lining for the aneurysmal sac, will naturally fall into place when the stitching is done

DIFFICULTIES IN THE WAY OF IDEAL TREATMENT—Unhappily, when dealing with the aneurysms caused by battle wounds, the surgeon not infrequently finds a field of operation in which anatomical details are much obscured In such a case he is better guided by general principles than by predetermined methods

Apart from a lack of anatomical definition there may be two special difficulties in these operations namely (1) to localize precisely the position of the fistula and (2) to effect adequate hæmostasis throughout the wound Profuse bleeding from numerous vessels often follows release of the tourniquet This is due to the collateral circulation which is especially well developed in the presence of an arterio venous aneurysm

LIGATURE.—The minimum of effective treatment consists in proximal and distal ligation of artery and vein as close to the fistula as possible This will cure some of these aneurysms but not all So long as any tributaries communicating with the portion of the artery lying between the two ligatures remain unsecured symptoms are likely to recur To overcome this risk various measures have been recommended The most radical is excision of the sac This though effective may be very difficult An alternative is to open the sac when the artery has been tied and to secure any bleeding vessels which can be found after release of the tourniquet Horsley recommended what he described as quintuple ligation (Fig 223) The artery and vein having been tied proximally and distally as close as possible to the fistula a stout catgut ligature is passed under both vessels above and below the affected segment and knotted so as to occlude any tributaries communicating with the sac between the proximal and distal ligatures

FIG 223 The quintuple ligature of Horsley

Treatment of traumatic arterio-venous aneurysms involving the cavernous sinus.—To minimize permanent injury especially to the eye early operation is required There are two alternatives ligation of the internal or ligation of the common carotid artery Ligation of the internal carotid might at first appear the more appropriate but it may be followed by hemiplegia owing to ischæmia of the brain in the region supplied by the middle cerebral artery General experience has proved this to be a considerable danger It seems preferable therefore to tie the common carotid at first This is easy it will bring some if only temporary relief it may cure the aneurysm and it is unlikely to cause hemiplegia If it fails the internal carotid may be tied later with less likelihood of causing hemiplegia the writer believes than if done as a primary operation

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SECTION VI

WOUNDS OF THE HEAD AND NECK

CHAPTER XXIV

INJURIES OF THE BRAIN AND SKULL

INTRODUCTION

THE aim of surgery is conservation of function Cerebral functions include the regulation of the vital internal economy of the body the adaptation of the organism to the variable conditions of external environment on the physical plane and to ever-changing situations on the psychic plane Without doubt the successful achievement of human aspirations including the victorious end of this war depends mainly on brain power The efficiency of each human unit engaged in the war depends more on his or her cerebral efficiency than on any other single factor In so far as surgery can conserve damaged British and Allied brains brain surgery has an important place in war surgery

Modern surgery implies much more than the manual operative act It involves in particular diagnosis assessment and decision operation when required and management until maximum recovery is attained In brain surgery diagnosis is based on neurology and psychology assessment decision and operations are based on these and on general surgical principles Management involves special nursing problems continued neurological and psychological supervision and continued special forms of treatment based on these It should be appreciated that while operative surgery is of great importance in many brain injuries of war it is but an incident in general management a large proportion of closed brain injuries do not require operation but come within the scope of management only

In this chapter it will be necessary to assume a sufficient knowledge of cerebral anatomy and physiology neurology and general surgery on the part of the reader Only special points in pathology diagnosis and assessment and in operative technique and other forms of treatment in the earlier stages of recovery can be dealt with

In war the brain is liable to damage—that is to injury such as impairs its function—from a variety of causes The most important injurious agents are physical violence and pathogenic bacteria Physical violence applied to the brain is common to both the open and closed varieties of head injury Bacterial infection is a problem of the open injuries only

The scalp and skull are but envelopes of the brain and are of importance only in so far as their condition may affect the enclosed brain It is of importance to visualize clearly the general structure of these enveloping parts Fig 224 shows the manner of division into *right* and *left supratentorial* compartments and the infratentorial compartment The supratentorial compartments are separated by the comparatively rigid falx cerebri, and they communicate with each other by the restricted archway beneath it. They communicate with the infratentorial compartment by the somewhat narrow incisura tentorii whose margins are rigid and sharp. The

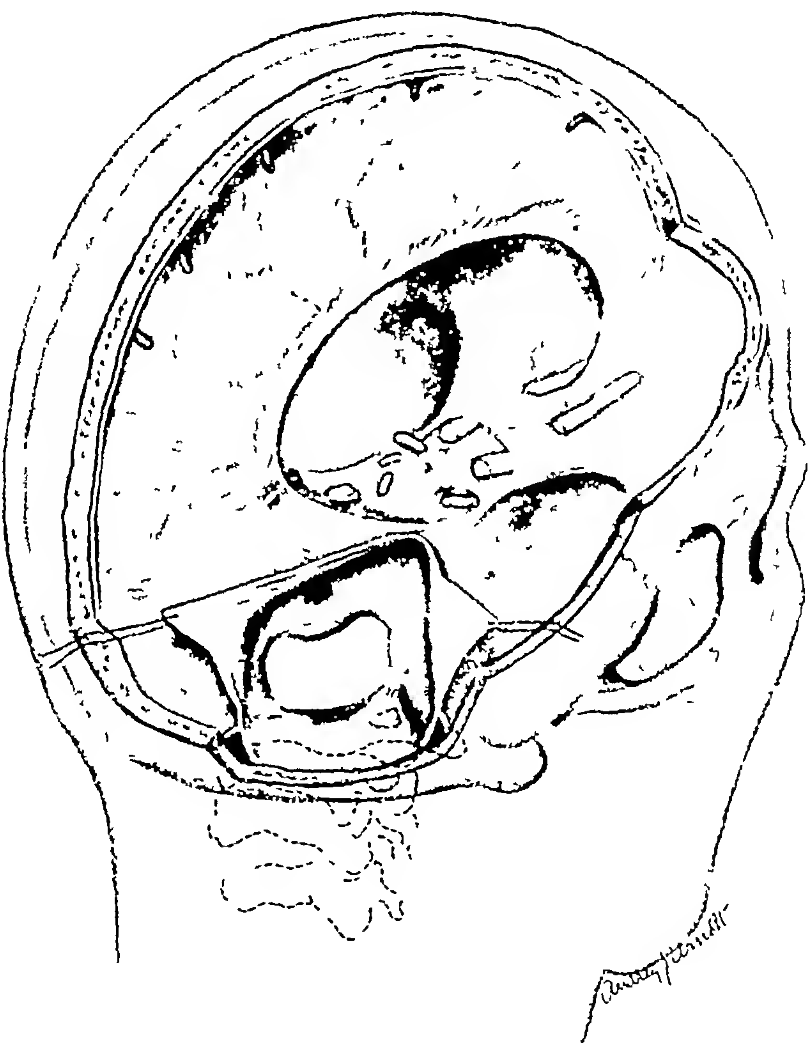

Fig. 224

The **chambers of the skull** enclosed by bone and dural partitions. Note their apertures of communication—the archway beneath the falx, the incisura tentorii and the foramen magnum. Note points of fixation of brain at olfactory bulbs, carotid arteries and cranial nerves, cerebral veins entering longitudinal and lateral sinuses.

infratentorial compartment opens into the spinal theca at the foramen magnum. The dural partitions do not yield quickly to a higher pressure on one surface. Thus if pressure increases rapidly, in hours or a few days, in one supratentorial compartment (Figs. 233 and 234) the falx and tentorium resist it, and pressure is higher within this compartment than elsewhere

The result is a damaging dislocation of the brain beneath the arch of falx—basal shift and through the same side of the tentorial aperture—tentorial impaction The former is marked clinically by impairment of consciousness the latter by signs of pressure on the cerebral peduncles—especially tremor and spasmodic rigidity in extension and of pressure on the homolateral oculomotor nerve—especially enlargement of the corresponding pupil If on the other hand the rise of pressure is more gradual extending over some weeks or more the dural partitions yield quite considerably (Fig 235) the increase of pressure is more equally distributed through them and the local deformations mentioned above are less in evidence Eventually however the pressure comes to bear at an aperture whose surroundings are bony and will not yield—the foramen magnum When impaction occurs here the striking features are neck rigidity spasticity of lower limbs and aggravation of hypertension by secondary hydrocephalus as the apertures of the fourth ventricle become blocked

The fluid circulatory system of the brain also deserves particular attention The fluid is formed in the ventricles at a considerable secretory pressure and obstruction of its circulatory pathway within the brain or sub arachnoid space or at the venous sinuses into which it ultimately passes occasions hydrocephalus—an excessive accumulation of cerebrospinal fluid under excessive pressure

SURGICAL ANATOMY AND SURGICAL TECHNIQUE

Hair of scalp—The hair of the scalp is the first anatomical problem we meet In the head injured it is often matted with blood mixed with road or masonry débris It must be removed to an extent of at least 3 in around the smallest scalp wound and from the entire scalp in the case of more extensive or multiple wounds The technique of hair removal has been studied and perfected over centuries by barbers In spite of the surgeon s heritage of ancient associations with barbering he is too often deficient in the technique and equipment for removing the hair of the scalp It may seem pedantic to dwell on this subject but the surgeon confronted with a head injured patient requiring urgent operation knows the practical im portance No satisfactory surgery of the head can be performed without good barbering The hair must be removed rapidly closely and without inflicting pain or additional wounds Necessary equipment includes hair clippers (preferably electric blades—1 and 0 1 mm) shaving brushes shaving cream in tube good quality razors and strop The use of scissors of ordinary soaps, of a swab for applying soap and of poor quality razors results in loss of time irregular and painful shaving and insufficiently extensive shaving Sterilization of the appliances is important so that infection may not be spread from case to case Clipper blades are disassembled and placed in equal parts of lysol and spirit Razors may be similarly sterilized Shaving cream in a tube is preferred so that that which remains in the tube is not exposed to infection. The brushes require at least twelve hours immersion in 1 20 carbolic lotion The care of the razors should be entrusted to a professional practising barber No razor should be laid aside after use without first stropping it It is perhaps unnecessary to describe the actual technique of shaving, but it should be realized that efficient shaving of the scalp is not an easy operation, and those who may be called upon to do it—or to see that others do it—should seek the advice of a barber if there is any doubt of their skill Experience indicates that sufficient skill in personal shaving of the face is no guarantee of ability to shave the scalp It is very desirable for any hospital or unit that may have to deal with head injuries to secure the services of a trained barber on its staff both for care of equipment and instruction to those who have to shave the head in emergency conditions

The Scalp.—Next we often have to induce local anæsthesia of the scalp The main thickness of the scalp consists of somewhat dense fibro-fatty tissue In the deepest plane of this run the larger nerves and blood vessels (Fig 225) The comparatively impermeable galea aponeurotica lies just deep to them and closely attached to the overlying tissues In order that the novocain-adrenalin solution may reach these nerves and vessels and so exercise its anæsthetic and hæmostatic properties effectively it must be

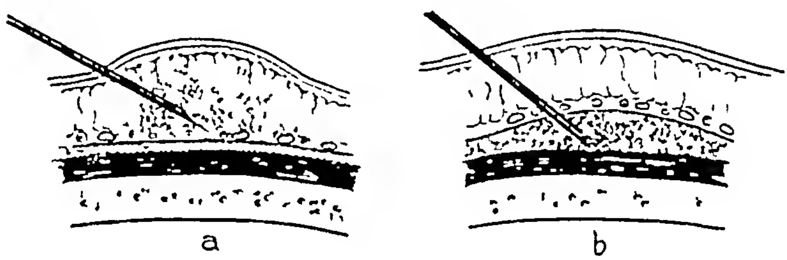

FIG 225

(*a*) Correct **novocain infiltration of scalp** The solution is diffused in fibro fatty tissue and acts on larger nerves and vessels in its deepest layer (*b*) Incorrect infiltration the needle has passed too deep and its point lies in subaponeurotic areolar tissue where the solution is ineffective on scalp as aponeurosis is relatively impervious

diffused in the fibro-fatty substance of the scalp As noted this structure is somewhat dense and tough, and its infiltration requires patience and considerable pressure If the needle is passed too deeply so as to penetrate the aponeurosis and enter the cellular layer between it and the pericranium, the fluid is very easily diffused into the loose cellular tissue It is prevented from reaching the nerves and vessels by the aponeurosis the scalp is merely raised up over the infusion and anæsthesia and hæmostasis are ineffective

The scalp is highly vascular Bleeding from an uncontrolled wound of the scalp is profuse and may well endanger the safe conduct of an operation by excessive blood loss at the outset It is mitigated by novocain-adrenalin infiltration but even with this the larger vessels bleed sharply Fortunately the scalp lies upon an even bony surface against which it can be effectively compressed (Fig 226) by the finger-tips For this, among other reasons, it is most convenient to employ two assistants for operations on the head The method is employed whenever scalp vessels are to be divided—in excising the edges of a wound in enlarging an accidental wound or in making the incision for a formal operation The illustrations sufficiently describe the application of the method Finger pressure must be maintained until the artery forceps have been applied and thrown over so as to evert the galea aponeurotica and draw it tightly over the cut surface of the scalp It is important that only the edge of the galea should be seized by the forceps If the fatty tissue of the scalp is caught necrosis and defective healing result

It should be noted that there are no important vascular connections between the scalp and the skull from a nutritional point of view There is no objection to reflecting an extensive scalp flap from the underlying peri

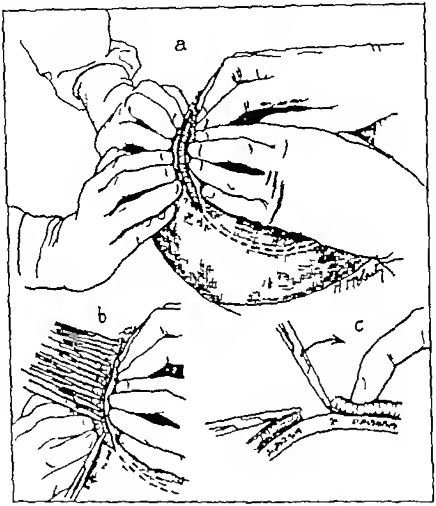

Fig 216

Technique of incision and hæmostasis of scalp

(a) Incision of scalp with edges compressed against skull by finger tips. (b) and (c) Mode of application of fine artery forceps to edge of aponeurosis and eversion of this by weight of forceps to occlude all severed scalp vessels. The procedure will be repeated as required as indicated by dotted line in (a)

cranium and this is usually the most convenient procedure to follow in making wide exposures of the skull and its contents Thus the scalp flap should be generous in dimensions and should have a wide base for its nourishment The procedure to be adopted for the underlying bone can be quite independent of the scalp

The skull is opened by minimal incision and scraping aside of its covering pericranium and by perforating the bone with drill and burr This provides sufficient access for exploratory brain puncture It provides the initial opening, which can be enlarged by nibbling forceps when removal of an area of bone is desired When reflection of a bone flap is desired a series of perforations is made along the line of proposed bone incision at intervals of 7 or 8 cm , and the bone is cut between the openings by wire saw (see Fig. 227), except at the base of the flap The flap is usually based on muscle either in temporal or occipital regions The base must be narrow enough to break readily The calvarial bone is nourished chiefly by the middle meningeal arteries This supply is necessarily sacrificed when the bone flap is raised from the dura There is an accessory supply from the external surface at muscle attachments—hence the preference for a muscle hinge at the base of the flap There is no doubt that large bone flaps are not adequately nourished from this source and are in large part free grafts Bone flaps make quite a satisfactory basis of skull repair even if completely severed from their connections, and even if subjected to boiling In all these circumstances the presence of devitalized or dead bone in the wound is an important factor and is successful only when perfect asepsis is assured Bleeding from diploic veins of the skull is often quite profuse It can be stopped easily by the impression of bone wax into the openings from which the bleeding comes It is usually necessary to nibble away a little bone at the site of fracture of the base of the flap, otherwise it will not fit readily into place again

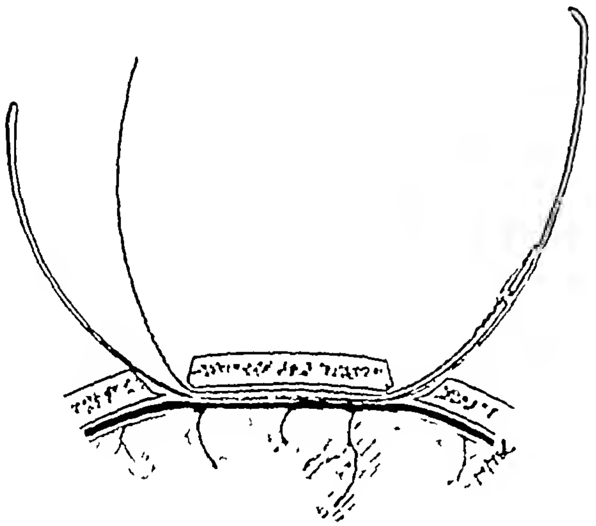

FIG 227
Opening of skull
Two perforations are shown Note bevelling of angles of bone to facilitate passage of guide between bone and dura The wire saw has been drawn through on the guide

It is of great importance that the instruments used for opening the skull should be of hardened rustless steel Their efficiency depends on their cutting edges Instruments of ordinary steel become corroded at their cutting edges, and are inefficient in use and also uneconomic as frequent resharpening and early replacement is necessary.

The dura mater carries the meningeal arteries and veins, which are adherent to its outer surface, and in its substance near the superior longitudinal sinus are the terminal portions of the superior cerebral veins and the lateral lacunæ of the sinus Bleeding occurs from these blood vessels when the membrane is exposed by removal of the overlying bone None of these vessels can be grasped by artery forceps except at the cut edge of the dura when it has been incised For bleeding from a venous channel of the dura the bleeding aperture is sealed by a fragment of muscle taken from exposed temporal or occipital muscle of the patient (Fig 228) The fragment is held firmly in place—most conveniently by a little piece of gutta-percha membrane over which a moist cotton-wool pack is placed for five minutes Clotting causes it to adhere quite firmly Bleeding from meningeal arteries and veins is most conveniently stopped by touching bleeding points lightly with coagulating diathermy current (Fig

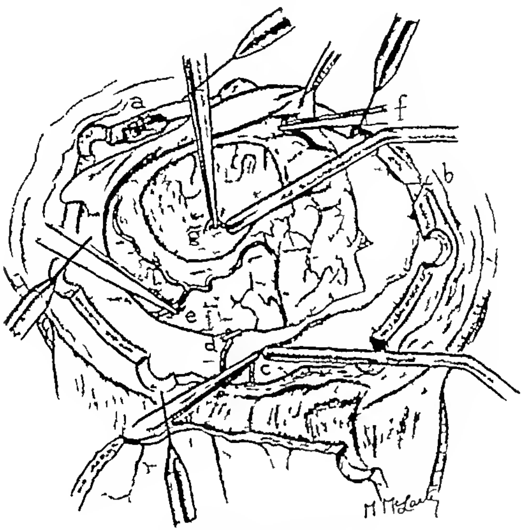

Fig 228

Several methods of hæmostasis

(*a*) Control of tear in dural sinus by application of fragment of muscle (taken from exposed temporal muscle). (*b*) Control of bleeding from dural vessels beyond bone edge by suture between dura and pericranium over bone margin (*c*) Control of torn bone nutrient branch of meningeal artery by touching with electro-coagulation; the bleeding point is kept free of blood by suction nozzle (*d*) *Silver clip* applied to meningeal artery at cut dural edge (electro-coagulation optional). ( ) Control of vein (or artery) on surface of brain by incision in arachnoid to isolate vessel, compression vessel with forceps and electro-coagulation (clip optional for larger vessels). (*f*) Similar control of a vein in its free course between brain surface and dural sinus. (*g*) Control of cerebral artery or vein in depths of a cerebral wound. The vessel is caught up in suction nozzle and thus held suspended and clear of blood It is occluded by electro-coagulation or (if large) by silver clip

228) Care must be exercised that the heating effect is not so extensive as to injure the underlying cerebral cortex The use of a suction tube in co-operation with diathermy is essential for the coagulation cannot be accurately localized unless the field is kept absolutely clear of blood When the

dura has been widely exposed it is necessary to expend considerable time and patience in coagulating every minute oozing point These points correspond to torn nutrient bone arteries These little arteries are relatively deficient in muscular coats and do not stop bleeding spontaneously as vessels of similar size elsewhere may be expected to do If not deliberately sealed before the wound is closed they will continue to bleed for hours or days, and may endanger life by forming a progressively enlarging extradural clot Bleeding often occurs from venous or arterial points just beyond and beneath the margin of the opening in the skull If intracranial pressure is high there may be no bleeding from this part but when pressure is released by further steps of the operation it may become troublesome It is most easily dealt with by securing the dura firmly up against the bone by a stitch, taking a shallow bite of the dura and passing over the bone margin to the pericranium of its outer surface (Fig 228) In the absence of diathermy all bleeding points on the flat surface of the dura must be stopped by muscle applications—a tedious process Vessels at the cut edge of the dura can be secured by applying Cushing's silver clips to grasp membrane and vessel together

The brain substance is of very friable texture It is readily injured by rough handling Its vessels also are more friable than similar vessels elsewhere in the body The brain tissue is so delicate that it is extensively injured and disrupted by bleeding into its substance which would do little harm to other body tissues The surgeon must have constantly in mind the importance to the patient of his brain and the fact that each neurone destroyed is not replaceable and is a permanent loss Hardly less important is the fact that cicatricial tissue in the brain substance induces epilepsy Adequate hæmostasis is the most important factor in avoiding unnecessary brain damage Actual loss of blood may or may not be important, but extravasation of blood into and around the brain is always seriously damaging It is quite impossible to use the ordinary methods of hæmostasis for the blood vessels of the brain The most delicate artery forceps merely tear the vessels and inflict appalling damage The bleeding brain cannot be controlled by packing the wound, for both the pack, and continued bleeding under it disintegrate the brain substance Diathermic coagulation and the suction tube are essential to all extensive operations on the brain Their method of application in various situations is sufficiently shown in Fig 228 Cushing's silver clips are used by preference for larger veins or arteries of the brain surface, or in the brain substance, as the extent of heating required to occlude them by diathermy is more damaging than is the clip It is possible in the absence of diathermy to effect hæmostasis by the use of clips for larger vessels and of muscle implants for smaller ones When it is necessary to incise the brain, a site as free of blood vessels as possible is chosen, and the incision is especially planned to avoid larger arterial branches All vessels of the surface in the line of incision are secured, and the leptomeninges and occluded vessels are then cut with a sharp knife or cutting diathermy current The incision is deepened with narrow spatulæ and all vessels in the brain substance are thus exposed, secured and deliberately cut with scissors

War surgery often presents the problem of brain substance, disintegrated and damaged by a wound and by subsequent bleeding It is necessary to remove all such damaged tissue until healthy brain tissue is exposed This is most conveniently accomplished by the suction tube at a vacuum pressure of 3 or 4 lbs per sq in and a tube aperture of about 4 mm This method has the advantage of removing damaged brain and clot rapidly keeping the field clear of blood and under control of vision and of leaving the larger blood vessels intact so that they can be easily secured or spared as may be appropriate

It should also be appreciated that intracranial surgical procedures often involve operating in a relatively narrow deep field Some form of special lighting is necessary A headlamp is generally the most convenient appliance to meet the conditions

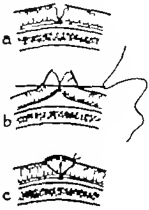

Fig 229

Closure of scalp

(a) Deep suture (interrupted) of fine silk apposing edges of aponeurosis. (b) Mode of insertion of superficial suture with straight needle (c) Superficial suture tied apposing skin edges and giving slight prominence or "heaping up effect" to suture line

Closure of the scalp—The scalp is a very vascular structure and has great vitality on that account Nevertheless local necrosis is readily induced by too tight stitching While delayed healing and a thick scar may be of no cosmetic importance on a hair covered part delayed healing and wound infection may prove fatal where the brain lies close beneath One has also to consider the possibility of further operative procedures—for cerebral abscess for excision of cerebral cicatrix etc A sunken scar from a first operation implies insecure closure of the wound for a second operation The method employed is to place a series of interrupted fine silk stitches to appose the edges of the epicranial aponeurosis (Fig 229) These are cut very short and are buried They take the main strain of the suture line on the fibrous avascular galea aponeurotica The cut surfaces of the scalp and skin edges are then apposed by interrupted silk stitches which are tied only just tightly enough to secure apposition The surface stitches are removed in forty-eight hours thus diminishing the incidence of stitch infections and necrosis

It will be appreciated that efficient operative surgery of war injuries of the head and brain requires certain items of equipment beyond the necessary instruments and materials These include surgical diathermy vacuum plant for suction special lighting facilities and a suitable head rest

MODES OF TRAUMA OF THE BRAIN

The brain may be injured within the intact scalp and skull or in association with wound and fracture of these envelopes. The injury to the brain may be localized multiple or diffuse

The kind of force applied—whether at high or low velocity whether by a light or heavy mass whether the line of force is perpendicular or tangential to the surface of the head at site of impact the shape size and consistence of the impacting object and the presence or absence of protective covering—determines the nature of the injury In the head itself the firm consistence of the skull and the weight and softness of the brain are important factors

The damage to the brain varies from temporary suspension of function without obvious anatomical change (concussional injury) to disintegration of its substance In all injuries with anatomically recognizable lesions hæmorrhage plays a dominant part in aggravating and extending an original mechanical rupture of tissue

Major Denny Brown and Major Ritchie Russell have recently shown that for widespread concussional injury the important factor is the rate of change of motion of the head, and they have accurately measured the critical change of velocity

Local percussional violence—This is well exemplified by a tangential gunshot wound of the head (Fig 230) By the impact which is of short duration and not sustained, the skull is momentarily bent inwards, at relatively high velocity, though for a short distance In the absence of extensive fracture it springs out again abruptly In the lesser grades of this type of violence there is produced a local concussional injury of the brain, which is clinically manifest in local loss of function—*e g* monoplegia, hemianopia etc —lasting from minutes to a few hours In severer grades of injury there may occur local rupture of brain tissue and especially, hæmorrhagic lesions from bursting of blood vessels by the sudden local reduction of pressure as the indented skull rebounds In this way serious extradural, subarachnoid or intracerebral hæmorrhages may be caused by an injury whose effect is local and which has not caused loss of consciousness

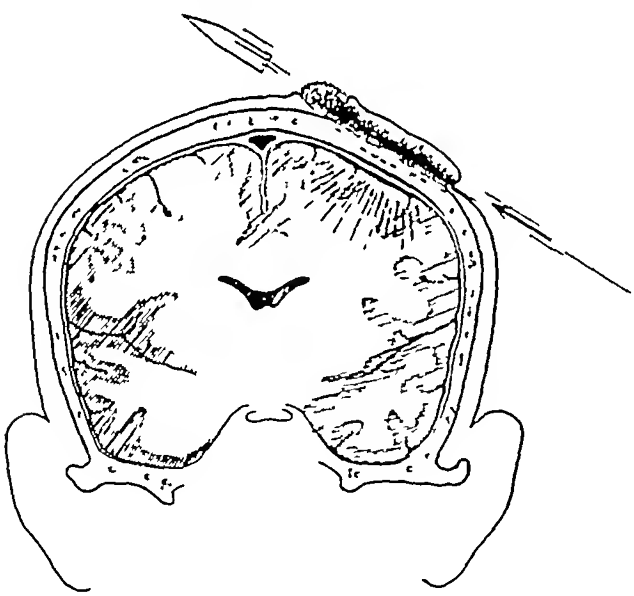

Fig 230

Local percussional violence

Exemplified by tangential bullet wound of scalp and skull The skull is locally and momentarily displaced by the blow The bending in is of small extent but at high velocity The underlying brain is locally percussed and its function temporarily deranged

Violence by momentum—By this is meant violence which involves an alteration of momentum of the entire head It may be that the head is struck by an object of relatively small mass at high velocity, *e g* , rifle bullet This conveys sufficient momentum to the whole head to alter its position abruptly It may be that a heavy blunt object, at lower velocity, strikes the head and moves it similarly Of equal significance is the abrupt arrest of the moving head by a massive resistance—as in a fall to the ground (Fig 231) Obviously the abruptness of movement or of arrest of the head depends among other things on substances intervening between the head and the object of impact. The crash helmet of the dirt track rider is familiar in this connection. The soldier's steel helmet not only mitigates the chances of penetration of the head but by its construction it softens the blow and helps to avoid that abrupt movement which is damaging. Such abrupt movement or arrest of movement of the entire head causes widespread concussional brain injury—an extensive depression or loss of function involving both lower and higher cerebral centres, which recovers usually in a matter of minutes or hours. When the local impact is severe local anatomical damage at this site may occur as described above. When the movement of the head is excessive the skull as a whole because of its stiff structure moves more rapidly than the soft heavy brain which tends to lag behind. This movement of the brain within the skull may cause a variety of widespread injuries depending on anatomical features. The brain may be flung against bony surfaces and ridges and against dural partitions—especially at the incisura tentorii—to produce anatomical and hæmorrhagic lesions. The brain may tear structures which fix it to the skull, such as the sixth and third cranial nerves, small arteries of the anterior basal region supplying the hypothalamus, optic chiasma and adjacent optic nerves, superficial cerebral veins near the longitudinal and lateral sinuses, or the deep cerebral veins near the vein of Galen.

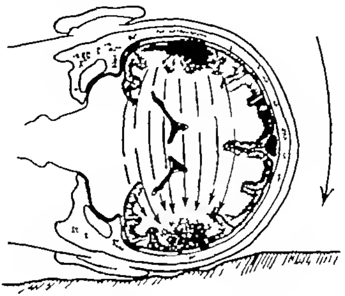

FIG. 231

Violence by momentum

Exemplified by fall on side of head. The rigid skull is suddenly arrested. The soft brain attempts to follow direction of force of momentum. There results an acute decrease of pressure opposite side of impact which causes rupture of veins and hæmorrhagic cerebral lesion (contrecoup). There also results an acute increase of pressure about site of impact; this may cause contusional lesions of brain though less extensive than by decrease of pressure. In addition there is usually percussional effect (see Fig. 230) spreading from site of impact (not illustrated here). Exactly the same physical result obtains when a massive blunt object strikes the head as when the head strikes such an object.

Contrecoup is an important factor in injury by momentum involving movement of the whole head. It is caused by the abrupt fall in local pressure in the region opposite the site of impact due to the different rate of acceleration or deceleration of the skull and brain mentioned above. When the head is struck on one side the rigid skull is abruptly "lifted away" from the slower moving brain at the other. When the moving head is arrested the brain "pulls away" from the suddenly arrested skull opposite the impact (Fig. 231). In fact practically no "lift" or "pull away" can occur, but the smaller veins of the region thus suddenly subjected to a partial vacuum are ruptured. A hæmorrhagic lesion ensues. This usually takes the form of multiple, small, intracerebral hæmorrhages and subarachnoid hæmorrhage Occasionally the arachnoid is ruptured and a subdural hæmatoma results Because of the hæmorrhagic—and so progressive—nature of the contrecoup injury it happens not infrequently that it produces the severest damage in cases of violence by momentum

Violence by penetrating missile—The extent of injury depends on mass, size and shape, and on velocity The mass, size and shape are obvious

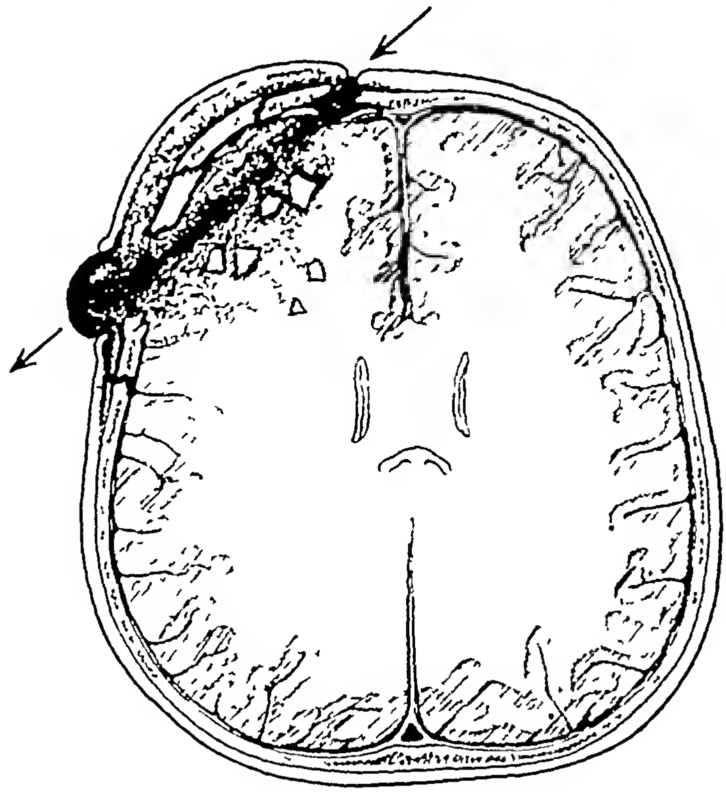

Fig 232

Violence by high velocity penetrating missile

A missile has passed through head as indicated It has produced penetrating fracture of skull at entrance and exit and has scattered fragments of bone along and around its track in brain A bursting fracture of skull has been produced by explosive effect of velocity A considerable volume of brain tissue has been disintegrated around the track through the brain Hæmorrhage is causing accumulation of clots and extrusion of damaged brain matter through external wounds

factors and require no further comment The velocity factor may be less apparent and is usually more important A small missile at high velocity produces relatively great damage by disruption of cerebral tissues around its track A larger missile at lower velocity may cause much less extensive damage Following close upon disruption of cerebral tissue, so produced, hæmorrhage occurs and aggravates and extends the damage (Fig 232) The skull is similarly affected at entrance and exit wounds It, too, like the brain, may be affected in a direction radial to the line of travel of the missile The force thus applied to the skull from within, through the medium of intervening brain substance may cause a bursting fracture (Fig 232) It is of interest to note that such a bursting fracture of the skull, though it implies considerable disintegration of adjacent brain substance may be compatible with survival of the patient

The brain may be injured by other types of penetrating wounds *e g* by bayonet thrust The wound thus inflicted does not differ materially in mechanical aspects from similar wounds elsewhere

MASSIVE INTRACRANIAL HÆMORRHAGE

Local hæmorrhages in the brain substance have been mentioned above in connection with local damage of brain tissue The massive intracranial

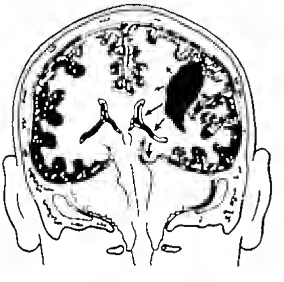

FIG 233

Acute intracerebral hæmorrhage

By local percussional violence or by contrecoup bleeding has been caused from vein near brain surface The leptomeninx has not been torn and the extravasated blood has excavated a cavity in brain substance. This is causing an acute increase of pressure in the right supratentorial compartment of the skull.

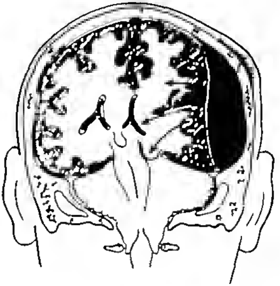

FIG 234

Extradural hæmorrhage

Blow on side of head with (or without) fracture of skull. Meningeal bone-nutrient arteries have been torn and resulting hæmorrhage accumulates between skull and dura mater Note that most acute compression effect falls on right supratentorial chamber of skull and there is a tendency to protrusion of brain substance through tentorial aperture on right side

hæmorrhages are such that by their volume they encroach on the intracranial space as to cause a serious rise in intracranial pressure The blood may be extravasated into the brain substance (Fig 233) into the subdural plane or into the extradural plane (Fig 234) Of these subdural hæmorrhage is the most frequent cause of serious clinical symptoms Their position and effects are sufficiently indicated by the illustrations and by the earlier remarks on the significance of the cranial chambers Treatment is by evacuation of clot and arrest of bleeding if it is still in progress The surgical exposure in these cases should be generous by a large bone flap as it is not possible to make an accurate clinical diagnosis of the exact site extent and concomitant injuries associated with one of these massive hæmorrhages

Chronic subdural hæmatoma (Fig 235) deserves special mention as it may cause symptoms to arise days, weeks, months, and even years after a head injury which had apparently recovered well A clot forms in the subdural plane, which at the time of its formation may cause slight if any symptoms Its outer layer becomes organized from the dura and this process may spread round to its inner layer also Meantime its central part liquefies and the fluid content becomes gradually increased so that the entire cystic structure acts as an expanding agent Its clinical effects are comparable to those of a tumour in a similar situation Distinguishing features which may or may not be present in the hæmatoma are a history of antecedent head injury and a yellow-tinged cerebro-spinal fluid with little or no increase in its protein content Treatment may be confined to making a burr hole in the skull incising the dura and outer layer of the hæmatoma sac and washing out its contents Drainage for a few days with a small tube or gutta-percha roll is advisable Sometimes persistent oozing of blood occurs from the walls of the sac so that it soon becomes distended again to its original size or more It is then necessary to expose the sac completely and to remove it It will be found to lift away readily from the arachnoid covering of the brain It is more adherent to the overlying dura mater, and separation of adhesions is associated with free bleeding from the dura The very numerous bleeding points must be sealed by coagulation with great care and patience, or the involved dura may be removed in whole or in part

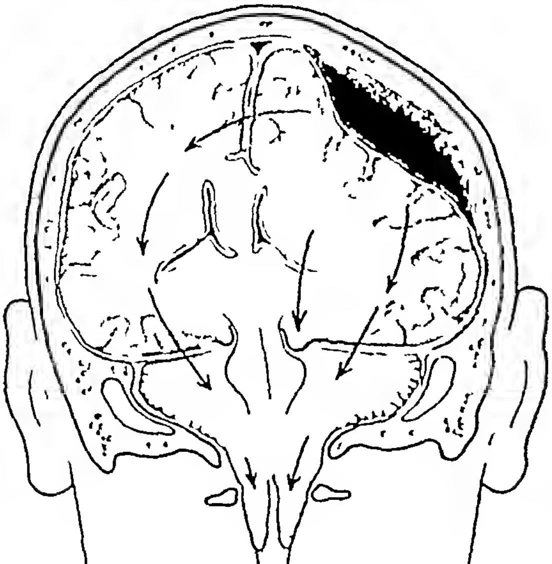

FIG 235

Chronic subdural hæmatoma

Blood from a torn vein on the brain surface has formed a clot between arachnoid membrane and dura The periphery of the clot has become organized (adherent to dura—non adherent to brain), the central parts have liquefied and the fluid content increased—thus acting as an expanding lesion Note that with this more slowly expanding (*cf* Figs 233 and 234) lesion, pressure is more evenly distributed as dural partitions yield in time, hence impaction at foramen magnum is an important effect

Damage to the brain by bacterial infection will be more conveniently considered later

FRACTURES OF THE SKULL

Simple fractures of the skull are usually of little clinical importance Rarely they derive significance from a depression of fragments sufficient to reduce the cranial capacity, or to indent the brain locally to such an extent as to maintain injurious pressure on it Such depressions should be elevated by operation In most cases the depression is insufficient to harm the brain and does not require treatment Simple fractures may derive importance from the damage inflicted by broken bone on an important structure other than the brain e.g the facial or ocular nerves the carotid artery and cavernous sinus Such complications rarely call for direct treatment applied to the fracture

Compound fractures are important because bone and especially comminuted bone is highly susceptible to bacterial infection Compound fractures include those associated with external wounds and those in which an internal wound opening into a natural cavity is caused by the fracture The former are for the most part wounds involving the dome of the head The latter are fractures of the base of the skull associated with tears entering an air sinus or nasal or aural cavities It should be emphasized that the parts of these cavities involved in fractures of the base of the skull are devoid of bacteria in normal health and infection of the fracture and of intracranial structures occurs only when the cavity concerned is the site of infective disease Fortunately therefore although these compound fractures of the base of the skull are of common occurrence infective complications from them are comparatively infrequent

In compound fractures of the vault of the skull all loose and devitalized bone must be removed This may involve extensive removal of bone but should be done without hesitation It is an easy matter to make good the bony covering of the brain by subsequent bone grafting if desired but if from failure to remove devitalized bone infection of the wound becomes established the consequences may be fatal or severely damaging to the brain When a compound fracture with external wound also involves the frontal sinus the opening into the sinus may be closed by application of a fragment of muscle If the walls of the sinus are extensively shattered a radical obliterative operation on the sinus should be included In the case of fractures involving ethmoidal and middle-ear cavities occlusion with a fragment of muscle usually suffices

ASSESSMENT DIAGNOSIS, DECISION

Assessment—When a head injured patient is brought in a general assessment is first made The exact circumstances surrounding the infliction of his injury are ascertained as far as possible If he has a wound is it actively bleeding ? If so bleeding of superficial origin should be stopped at once by firm pressure temporary stitches in the scalp or temporary application of artery forceps If the bleeding comes from the depths light packing of the superficial wound may mitigate it One also ascertains if the patient is conscious or unconscious. The degree of shock if any is noted and is treated at once if severe The position and general distribution of wounds is observed Wounds should not be explored by probing nor elaborately dressed until formal operation is undertaken Bruises or hæmatomas are noted Escape of blood or cerebro-spinal fluid from nose ears or mouth is noted Injuries elsewhere are searched for and their influence on general condition and management is determined If at all possible information is elicited to show whether the general condition especially in respect of circulation and consciousness has been improving or deteriorating since receipt of the injury

It should be emphasized here that in the case of wounds by missiles the smallest scalp wound should be regarded as possibly serious even if the patient is a "walking case" and shows no apparent disability Such a small wound may be the entrance puncture of a missile which has entered the skull and brain It should also be mentioned here that head injury cases even the most serious, take little or no harm from efficiently managed transport The only serious factor for consideration is the time factor Especially in cases requiring operation time spent in transporting the patient to a hospital where adequate equipment and staff are available is usually to the patient's ultimate advantage

Diagnosis—After these preliminary steps a careful examination of the nervous system is carried out Neurological and psychological functions are systematically investigated as fully as possible The extent of the examination is obviously determined by the state of consciousness of the patient In the unconscious patient no psychological tests can be applied, nor can any tests depending on volition or co-operation be made one is restricted to observation of lower level reflexes of motor behaviour, including defensive actions and facial expression of muscle tone etc In the absence of increased intracranial pressure and in the first twenty-four hours after injury, one is justified in assuming that loss of a given function is due to direct injury of the nervous mechanism concerned by concussion laceration, or local hæmorrhagic damage From such an examination one may gain exact knowledge that a particular portion of the brain, subserving for example, certain elements of vision and certain language functions, is out of action On the other hand one may merely gain the information that most of the brain is out of action and it may be impossible to deduce at the time whether this is due to widespread concussion which will recover or whether and to what extent more permanent damage has been done

The diagnosis of increased intracranial pressure is important because it is often a progressive factor, endangering life and usually susceptible of relief by suitable treatment As seen in those who have sustained head injuries, the clinical picture rarely accords with the classic formula of deepening drowsiness, slowing pulse and rising blood pressure A notably slow pulse is much more common in patients without raised intracranial pressure and is often referable to concussional derangement of the central heart-regulating nervous mechanism Similar considerations apply to drowsiness and to impairment of consciousness Not infrequently the blood pressure is lowered in cases of increased intracranial pressure following trauma, and it may rise significantly when the pressure is relieved by treatment In the majority of cases of seriously increasing intracranial pressure following head injury, the patient is confused but also restless and often violent in his behaviour, the pulse and respiration rates are notably increased, and the temperature is often moderately raised The symptoms increase progressively over a period of hours and finally end in an abrupt onset of coma, followed by death in a few minutes or hours When coma develops in these circumstances it is usually too late to take action for relief This clinical picture may be modified profoundly by the presence of concomitant brain injuries, *e g*, the patient may be in profound coma from the first, by reason of severe concussion If a patient has made a considerable degree of recovery from initial concussion, and subsequently deteriorates in respect of further impairment of consciousness, of increasing restlessness or of increase in respiratory rate and amplitude there is reason to suspect a progressive massive intracranial hæmorrhage This is the most frequent cause of such deterioration after a lucid interval It is not however the only cause and of others an extending thrombosis of the internal cerebral venous system spreading from veins injured by the original trauma is not uncommon

In connection with the lucid interval syndrome it is important not to confuse a true deterioration of cerebral functioning with the very common false variety After concussion there is often a state in which consciousness is depressed and is only maintained under the influence of a strong stimulus Thus (as Group Captain C P Symonds kindly reminds me) a pilot having sustained concussion on crashing may come to himself in a few seconds He may then turn off the petrol unstrap his harness get out of the cockpit and help others out of the machine he may walk a distance for assistance Having accomplished these urgent tasks he may lapse into stupor and fail to respond to stimuli of a less rousing character than those which actuated him for some time after the crash The condition of the injured man has not necessarily become worse On the contrary his injured brain may be resting having nothing of sufficient urgency to keep it awake The important criterion is that the patient can be roused again to consciousness provided a sufficient stimulus is applied It requires a stronger stimulus to awaken consciousness than to maintain it and a potent stimulus such as tickling the ribs may be required This test should be applied in all cases of doubt It should not be repeated unnecessarily but it should be repeated if there is any suspicion that the condition is deteriorating For example the nurses in attendance should be instructed that if the breathing of the stuporose patient should become deeper or stertorous they should stimulate him sufficiently to ascertain that he can be roused, and should report at once failure of adequate response

It is clear that the diagnosis of a significant increase of intracranial pressure in head injury cases is difficult and often impossible to make from clinical examination alone because of the frequency of complicating factors Papillœdema may develop early and afford a clear indication but it may not show for hours or days in spite of a high sustained pressure Much the most reliable criterion is the pressure of the cerebro-spinal fluid ascertained at lumbar puncture There is no doubt that in head injury cases chief reliance should be placed on this simple test In order to obtain reliable information the patient must be relaxed and quiet and the pressure must be measured If the patient is restless violent or tense it is advisable to give an intravenous anæsthetic to secure relaxation To measure the pressure all that is required is a narrow bore glass tube 40 cm long which can be attached to the lumbar puncture needle by a short length of rubber tubing A pressure of 300 mm of fluid or more is to be regarded as requiring treatment for its relief

Having ascertained the presence of seriously increasing intracranial pressure its cause and the location of the cause must be diagnosed before treatment can be undertaken When there is evidence of progressive paresis or lack of reaction to sensory stimuli on one side of the body and the pupil on the opposite side becomes progressively dilated it is likely that a patient is a "walking case" and shows no apparent disability. Such a small wound may be the entrance puncture of a missile which has entered the skull and brain. It should also be mentioned here that head injury cases, even the most serious, take little or no harm from efficiently managed transport. The only serious factor for consideration is the time factor. Especially in cases requiring operation, time spent in transporting the patient to a hospital where adequate equipment and staff are available is usually to the patient's ultimate advantage.

Diagnosis—After these preliminary steps a careful examination of the nervous system is carried out. Neurological and psychological functions are systematically investigated as fully as possible. The extent of the examination is obviously determined by the state of consciousness of the patient. In the unconscious patient no psychological tests can be applied, nor can any tests depending on volition or co-operation be made: one is restricted to observation of lower level reflexes of motor behaviour, including defensive actions and facial expression, of muscle tone, etc. In the absence of increased intracranial pressure and in the first twenty-four hours after injury, one is justified in assuming that loss of a given function is due to direct injury of the nervous mechanism concerned by concussion, laceration or local hæmorrhagic damage. From such an examination one may gain exact knowledge that a particular portion of the brain, subserving, for example, certain elements of vision and certain language functions, is out of action. On the other hand one may merely gain the information that most of the brain is out of action, and it may be impossible to deduce at the time whether this is due to widespread concussion which will recover or whether and to what extent more permanent damage has been done.

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All cases of penetrating or other compound fracture of the skull should be examined by X ray before the plan of operation is decided

All cases of compound fracture of the skull due directly to an external

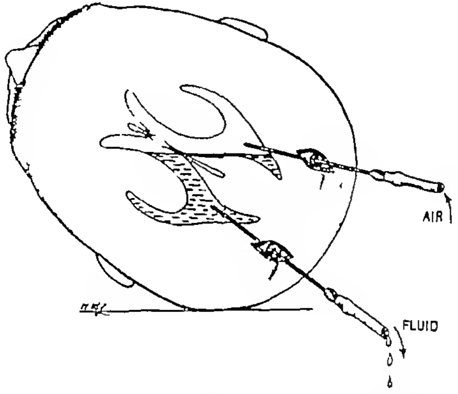

FIG 236

Ventricular puncture and replacement of ventricular fluid by air Note the position of the head to ensure complete replacement. The scalp incisions are held open and bleeding from them is controlled by small (mastoid) self retaining retractors. The incisions are usually placed somewhat further back than the drawing indicates.

agent and all cases exhibiting a dangerous increase of intracranial pressure require urgent operation When operation is inevitably delayed patients with open wounds should receive adequate chemotherapeutic dosage

Most cases of brain damage without external wound and without a dangerous increase of intracranial pressure do not require operative treatment Patients with escape of cerebro-spinal fluid from nose or ears in fractures involving the base of the skull rarely require operation They too should receive chemotherapeutic treatment as a matter of precaution If there is evidence of infection of the cavity into which the fluid is escaping or if the leakage persists beyond two weeks it should be stopped by operation This involves adequate opening of the cranial cavity exposure of the aperture on its endocranial aspect and sealing of the aperture by the application of a fragment of fresh muscle to it local increase of pressure exists in the corresponding supratentorial compartment These signs are of value in localizing a massive hæmorrhage only when they are observed to develop concurrently with its more general effects In the absence of this relationship the localizing signs may be quite misleading For example, dilated pupils and hemiplegia may be due to a minute, intrinsic hæmorrhagic lesion in the midbrain and have no direct relationship to increasing intracranial pressure It will be appreciated that the localization of an increasing massive hæmorrhage may be as difficult or impossible from clinical evidence alone as is the diagnosis of increasing pressure

In these circumstances we can employ methods of special examination Exploratory cranial punctures can be made quickly and safely If there are any suggestive clinical signs, the suspected situation is naturally examined first In the absence of such signs a puncture is made at each parietal eminence and if necessary, over each lower post-frontal region At any given situation puncture may disclose an extradural accumulation of blood If not, the dura is opened when a subdural clot may be exposed If the brain surface is normal but tense an exploring cannula is inserted and aimed at the ventricle Intracerebral clot may be encountered When the ventricle is reached its state and size can be deduced by touch and by the quantity of fluid which escapes A small, collapsed ventricle on one side indicates an expanding lesion on that side of the brain Dilatation of both lateral ventricles suggests that the expanding agent is in the posterior cranial fossa—a somewhat infrequent event in traumatic cases

If exploratory punctures have failed to give such information of the cause of increasing intracranial pressure as permits the planning of surgical procedure for its relief, it is necessary to carry out ventriculography By this means the anatomy of the cerebral ventricles is revealed in the X-ray picture, and from this additional information a correct estimate of the location of the lesion is always possible

In such cases a very generous operative exposure is desirable, and a central bone flap on the side indicated, mobilizing at least two-thirds of the area of this half of the skull should be made This wide exposure is desirable because progressive hæmorrhagic lesions usually cannot be accurately localized, and they may be multiple Moreover massive cerebral œdema developed around large or multiple hæmorrhagic lacerations of the brain substance may be encountered instead of the expected massive hæmorrhage This type of œdema requires very wide decompression such as is afforded by the large flap The classical subtemporal decompression fails entirely to meet its needs The large bone flap is, of course, allowed to ' float " on the expanded brain surface After five or six days the swollen brain recedes and the flap settles down into its place to reconstitute a serviceable and practically intact skull

In cases in which increasing intracranial pressure develops days or weeks after injury and in which clinical symptoms and signs leave doubt as to the nature and location of the responsible pathology, the problem is approached as for brain tumour, etc Ventriculography may be carried out as indicated in Fig 236, and subsequent treatment is planned according to the findings of this examination For chronic subdural hæmatoma the simple operative principle of importance The method of cruciate enlargement of an existing wound to deal with an underlying craniocerebral injury is strongly

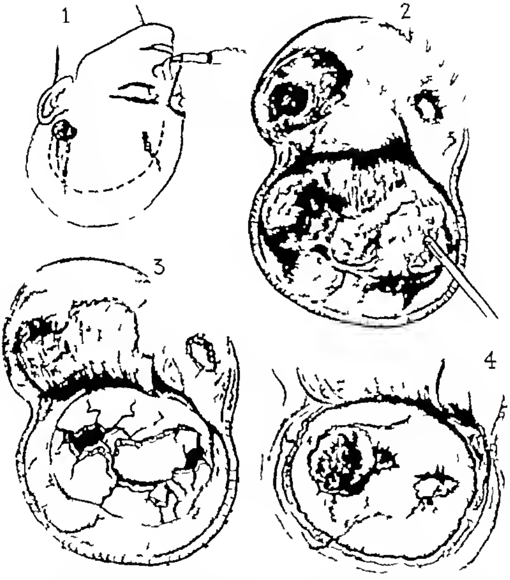

Fig 233

(1) Gunshot wound of head rifle bullet, entrance to left of centre of forehead exit left temple; X rays have shown extensive comminuted fracture between (cf Fig. 232) Prepared for operation—note intratracheal anæsthesia tube and complete shaving Outline of incision indicated. (2) Scalp flap reflected extruded and disintegrated brain matter and clots removed by sucker (3) Flap of periosteum and temporal muscle reflected to expose comminuted fracture (4) Damaged and loose bone removed, including anterior and posterior wall of shattered frontal sinus wounds of dura exposed clot and débris protruding from exit wound.

deprecated it leads to inadequate exposure and to complications of healing The external wounds were not touched at the outset but were turned aside with the scalp flap and were excised and sutured as the last stage of the operation

TREATMENT OF SCALP WOUNDS

These should be regarded as potentially serious. This is especially true of war wounds for the bruising of underlying bone and brain which often results from gunshot wounds renders these deeper structures more susceptible to infection than in wounds in time of peace Moreover, as already indicated war wounds furnish more "surprises" especially if an X-ray examination has not been available The operator who thinks to excise and stitch a simple "cut head" in a dressing station or in other unsuitable surroundings will not infrequently find himself involved in a case of serious penetrating compound fracture.

Ideally, after adequate examination each case of scalp wound should come to formal operation in a well-equipped operating room where any contingency can be met Anæsthesia should be adequate—either a wide circle of novocain infiltration or general anæsthesia maintained through a tracheal tube. The wound edges should be sparingly and bloodlessly excised and the depths thoroughly inspected. The wound should be enlarged if any damaged area remains obscure Having removed all damaged tissue and any foreign material, hæmostasis is carefully attended to. It is preferable to seal larger bleeding vessels of the scalp by diathermic coagulation than to rely on tight suturing for this purpose The wounds heal more kindly, and with a diminished incidence of infection if so managed. If an area of scalp has been removed so as to render closure difficult, closure can often be accomplished by enlarging the wound in "S" or reversed "S" formation The insufflation of sulphanilamide powder upon the wound surfaces before closure further reduces the incidence of infection Suppuration has been very rare in wounds so treated within the first twenty-four hours The extremely serious consequences of scalp wound infection will be mentioned later.

TREATMENT OF COMPOUND FRACTURES OF THE SKULL

The principal features of operative treatment are illustrated in Figs 237 and 238. The illustrations were taken from an actual case operated upon six hours after the injury and in which after ten days the patient had no remaining disability of any sort. Some doubt was felt as to the advisability of transferring this man to a unit equipped for brain surgery. He was however, transported a distance of twenty miles by ambulance on a winter's night with snow falling. On admission, concussion was passing off and the patient was conscious He was considerably exsanguinated, and a transfusion of blood was begun and continued throughout the operation, most of the blood being given towards its conclusion. X-ray examination and clinical examination were made. In this case gas and oxygen anæsthesia was administered through the intratracheal tube. Local anæsthesia might have been employed but would have been more difficult to make efficient as the base of the skull, frontal air sinus, etc., were involved.

In this case the whole damaged area, including entrance and exit wounds, were included by free exposure in a large scalp flap. This is a principle of importance The method of cruciate enlargement of an existing wound to deal with an underlying craniocerebral injury is strongly

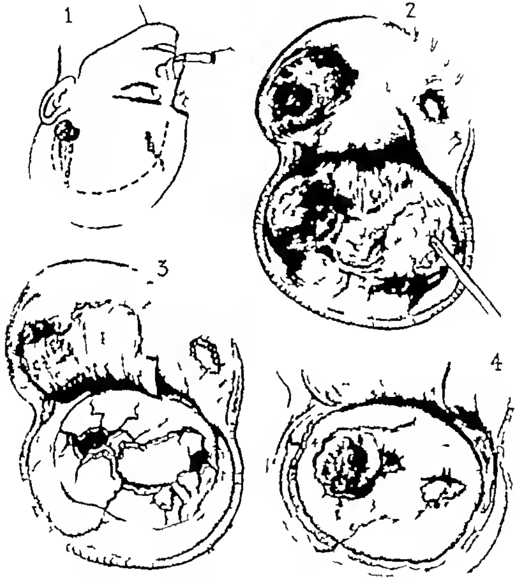

FIG 233

(1) Gunshot wound of head rifle bullet, entrance to left of centre of forehead; exit left temple; X-rays have shown extensive comminuted fracture between (cf Fig. 232). Prepared for operation—note intratracheal anæsthesia tube and complete shaving Outline of incision indicated (2) Scalp flap reflected extruded and disintegrated brain matter and clot removed by sucker (3) Flap of periosteum and temporal muscle reflected to expose comminuted fracture (4) Damaged and loose bone removed including anterior and posterior wall of shattered frontal sinus wounds of dura exposed; clot and débris protruding from exit wound.

deprecated it leads to inadequate exposure and to complications of healing The external wounds were not touched at the outset but were turned aside with the scalp flap and were excised and sutured as the last stage of the operation

The flap having been planned and outlined, the head was securely draped with moist, soft towelling, which could be accurately and smoothly applied to the rounded contour of the head and to the outline of the flap The

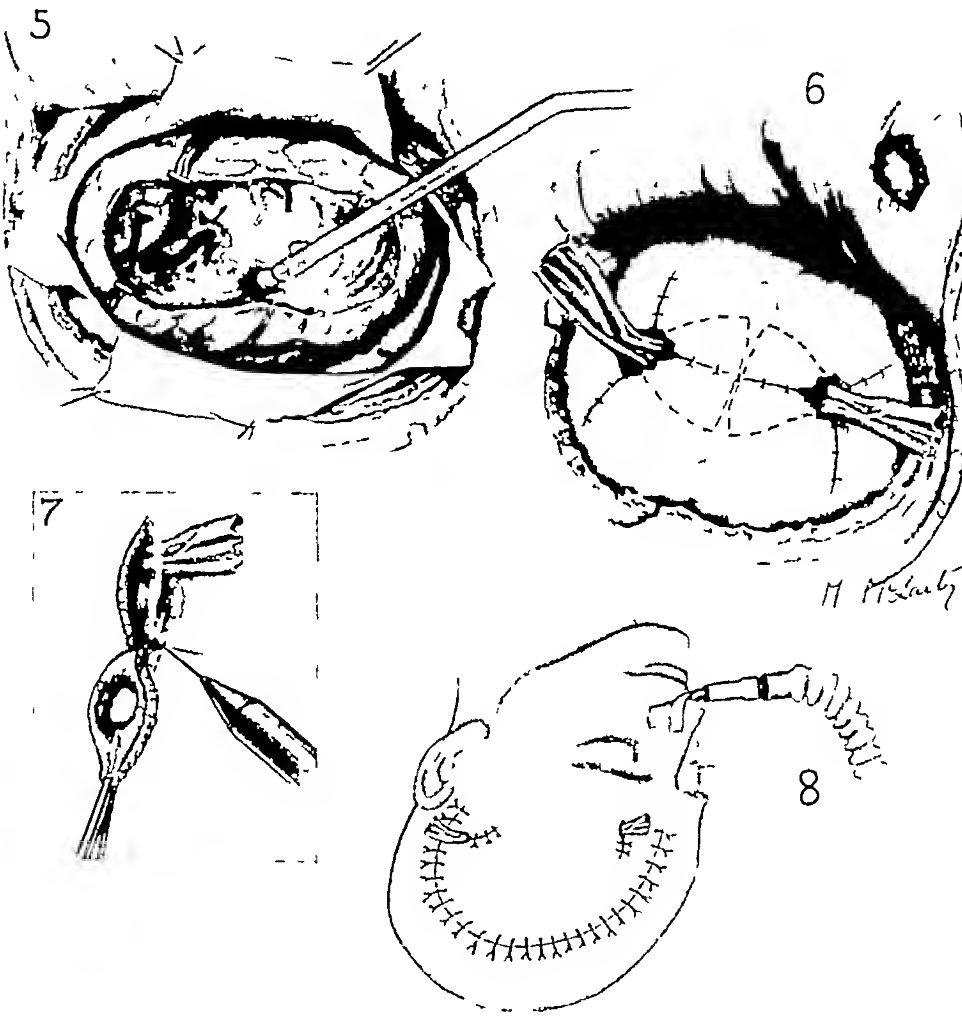

Fig 238

(5) Dura opened, damaged brain tissue, clots and bone fragments removed by suction leaving considerable cavity in brain with healthy tissue in its walls cerebral vessels secured as required by electro coagulation or clips, mucous lining of frontal sinus has been removed and its duct occluded by muscle fragment (6) Dura closed guttapercha drains spread fanwise over damaged brain surface, ends of drains brought out through entrance and exit tears of dura (7) Excision of margins of scalp wounds by diathermy (or by knife) (8) Periosteal muscle flap has been loosely replaced, scalp flap accurately sutured, entrance and exit wounds partially sutured around drains

further steps of the operation are sufficiently shown by the illustrations All facilities of suction apparatus, diathermy and special illumination were essential to success The rate of transfusion was controlled by frequent observations of the patient's blood pressure The utmost care in hæmostasis was observed throughout, and especially as the several steps of the operation were concluded This care was necessary not so much to avoid blood loss as to avoid bleeding which would inflict further damage on the brain or interfere with rapid wound healing Sulphanilamide powder was insufflated upon the exposed tissues other than the brain The operation occupied four hours Wound healing was satisfactory Stitches were removed on the second day drains on the fourth day The patient exhibited transient dysphasia which had disappeared within three days He was up on his feet within a week From the tenth day no physical or psychic defect of brain function could be detected in spite of the considerable loss of left frontal brain substance The large defect in the skull occasions no inconvenience to this man It could readily be made good by bone grafting if for any reason this appeared desirable In relation to modern war injuries considerable encouragement may be taken from such cases as this The wound was inflicted by a service rifle bullet at a range of 15 ft and the velocity of the missile was such as to burst the skull outwards Yet he recovered without residual disability

In all cases it is essential that exposed bone and brain should be covered by sound scalp If a considerable area of scalp is missing scalp tissue must be borrowed to cover the vital area even if this means denuding another area where bone and pericranium are intact Such a denuded area will granulate satisfactorily and can be treated by skin grafting if desired

It is impossible in the space and time available to dwell at greater length on the many variations of craniocerebral wounds and their management It is hoped that the case selected for description will convey the general principles involved, which are applicable to all cases

The **dressing** of wounds of the head merits particular attention. The types of swabs and bandages suitable for the limbs or the abdomen are unsuitable for the rounded head Ordinary small swabs take no hold and are apt to become displaced The domette and open woven muslin bandages are too unyielding do not lie well and become loosened. Cotton wool sticks among the stubbly hairs of the recently shaved scalp and should be used only for protecting the ears The liberal use of sterile vaseline keeps the skin in good condition and adds much to the patient s comfort It renders the first change of dressings much easier by preventing sticking Importance is attached to the large folded triangle of surgical gauze which is applied to envelop the entire head (Fig 239) It holds all separate swabs securely in place It can be rapidly applied to a restless patient and the final securing bandage can be applied afterwards much more easily

INFECTIVE COMPLICATIONS OF WOUNDS OF THE HEAD

Septic thrombo phlebitis of intracranial venous channels meningitis or cerebral abscess may be the consequences of infection of a scalp wound. The mode of spread of infection is partly along tissue spaces such as the cellular layer of the scalp and the extradural plane but mainly by extending venous thrombosis (Fig 240) The probability of serious intracranial infection is obviously increased when a compound fracture is present The brain of course may be *directly* contaminated when penetrated by an

The flap having been planned and outlined, the head was securely draped with moist, soft towelling, which could be accurately and smoothly applied to the rounded contour of the head and to the outline of the flap The

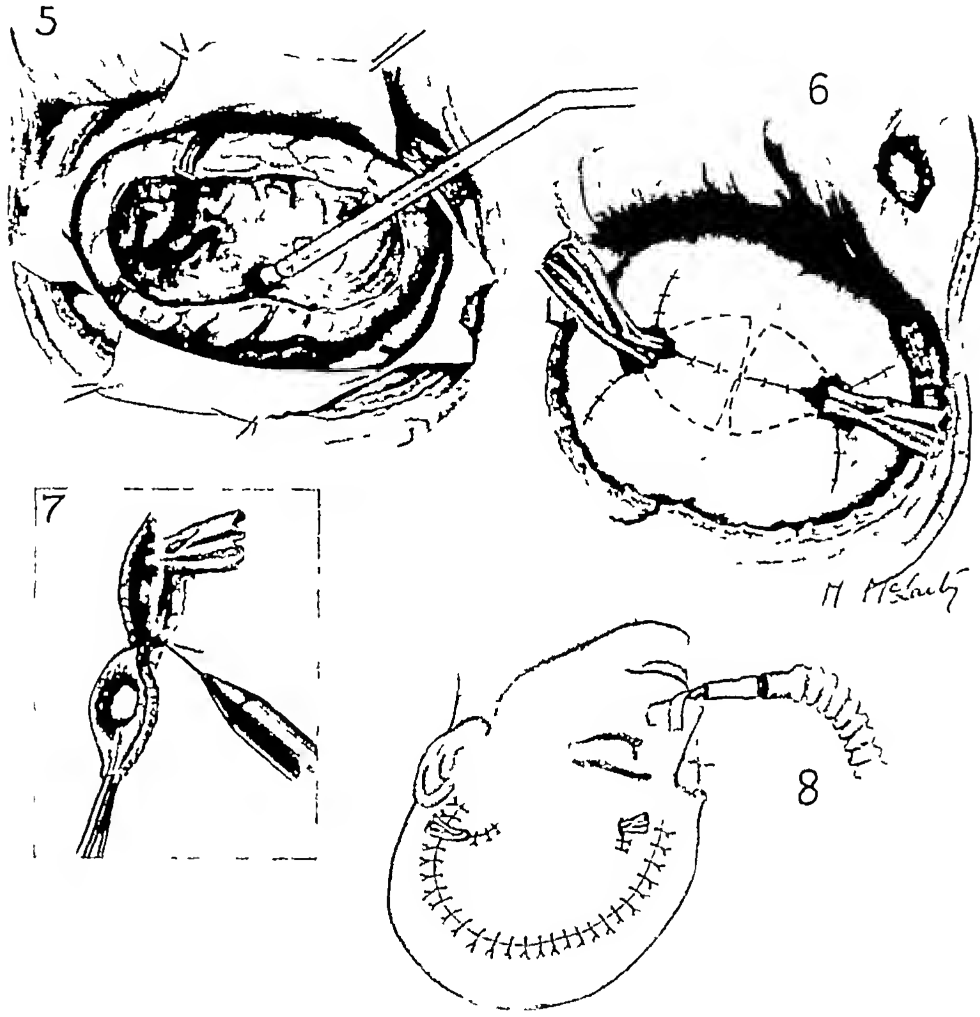

Fig 238

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further steps of the operation are sufficiently shown by the illustrations All facilities of suction apparatus, diathermy and special illumination were essential to success The rate of transfusion was controlled by frequent observations of the patient's blood pressure The utmost care in hæmostasis was observed throughout, and especially as the several steps of the infected object Undoubtedly the principal duty of the surgeon in this connection is to avoid the establishment of wound infection by the means

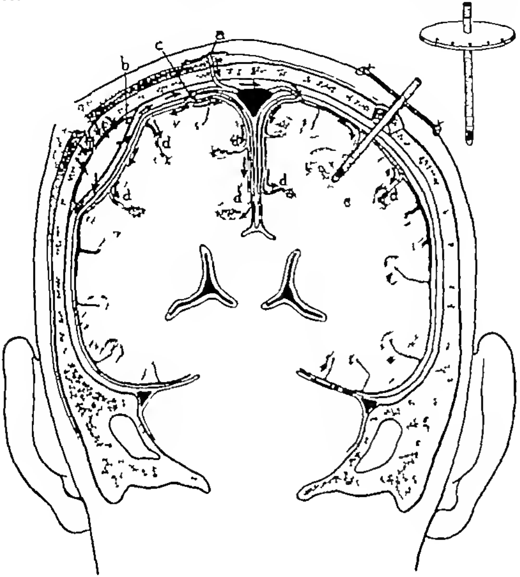

FIG 240

Several modes of spread of infection in wounds of head

A scalp wound has become infected. (1) The subaponeurotic areolar layer may become seat of cellulitis which may reach emissary vein (a) and cause infective thrombo-phlebitis of it which may spread intracranially ( ) Infection may spread through torn pericranium, Haversian canals of bone or fracture if present to extradural plane—extradural abscess (b). Infection may spread in small veins of dura and involve a cerebral vein in its passage through the dura. Infective thrombo-phlebitis of a cerebral vein (c) may cause meningitis as it spreads inwards, and/or cerebral abscess as branch veins (d) draining brain substance become affected. The infection may spread through dura of the walls of a dural sinus (with or without thrombosis of sinus) and so reach opposite side where similar spread along cerebral veins may take place Method of drainage of a recently formed cerebral abscess (e) by rubber catheter supported by a disc at scalp surface is also shown

already discussed and especially by treating scalp wounds as serious injuries and operating formally and deliberately for them also by removing all devitalized bone and by removing all clot and disintegrated brain tissue

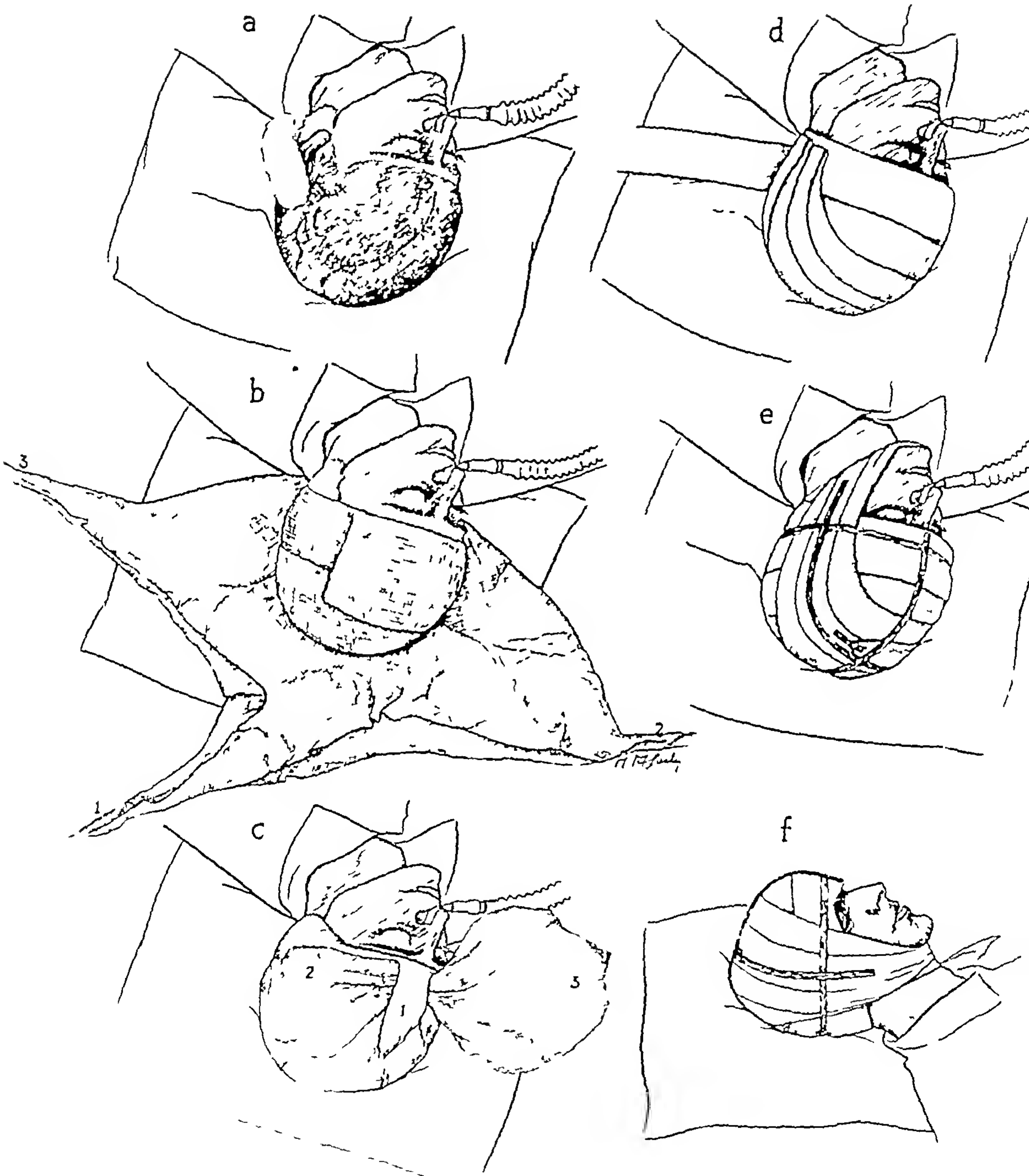

FIG 239
Dressing the head

(*a*) The scalp of the operation area has been heavily smeared with sterile vaseline, the ears have been similarly smeared and cotton wool pads applied behind and over each ear (*b*) Large gauze swabs wrung out of mild antiseptic lotion (*e g*, perchloride of mercury 1 2,000) have been applied widely over operation area, gauze square arranged in triangle form—two layers—placed beneath head ready for application (*c*) Gauze triangular bandage applied—ends spread widely over entire head (*d*) Gauze roller bandage applied in transversely disposed capeline style (*e*) Final turns of bandage pass under chin and spread fanwise over head, turns of bandage secured by ½ in adhesive strapping applied in horizontal, sagittal and coronal planes (*f*) Same showing fanwise disposition of last three turns of bandage and application of adhesive strapping infected object Undoubtedly the principal duty of the surgeon in this connection is to avoid the establishment of wound infection by the means

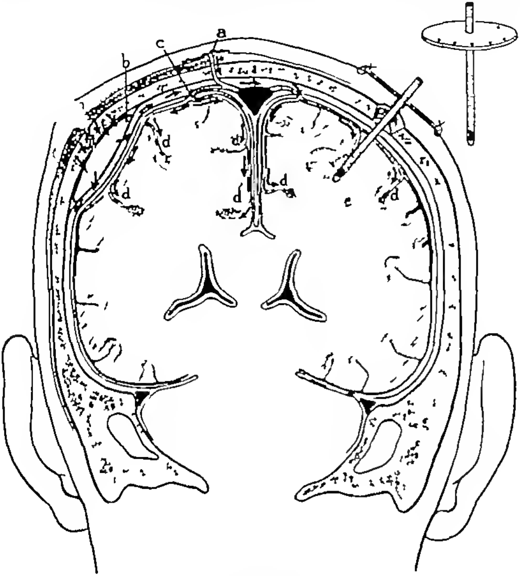

FIG 240

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already discussed and especially by treating scalp wounds as serious injuries and operating formally and deliberately for them also by removing all devitalized bone and by removing all clot and disintegrated brain tissue

There may be difficult decisions to make in this connection A patient with a compound fracture of skull may appear unlikely to recover from his primary cerebral injuries There may be no indications to operate for his cerebral injuries Is the surgeon to operate with a view to preventing the establishment of wound infection or not? Few situations are more difficult of assessment than the probabilities of recovery in the first twenty-four hours following a severe brain injury Obviously, in normal circumstances, the choice must lie in favour of operating to avert future wound infection, even though this involves accepting a high proportion of disappointments from those patients who fail to recover A properly conducted operative treatment of the compound fracture will in no circumstances impair the chances of recovery from primary cerebral injuries

When, from any cause, wound infection has become established, we have to deal with its complications **Septic meningitis** is easily recognized clinically and by lumbar puncture The prognosis of this serious complication has been much improved by chemotherapy This should be pushed as far as tolerable The cerebro-spinal fluid pressure should be measured, and if it is significantly raised, continuous drainage through the lumbar puncture needle into a receptacle set at a "head" of about 150 mm of fluid should be arranged The needle should be freshly inserted through another lumbar interspace at intervals of twenty-four hours

Septic thrombo-phlebitis of intracranial venous channels—Little can be done to mitigate this in its acute form beyond the institution of adequate chemotherapy It is well to bear in mind, however, that subacute forms occur Also non-infective, or at least non-suppurative, thrombosis may spread into cerebral venous sinuses and cerebral veins The resultant focal cerebral symptoms, including localized epileptic manifestations, localized paretic phenomena and localized œdematous swelling of the brain, may closely simulate those of cerebral abscess The swelling may be such as to require operative decompression for its relief No pus forms, the swelling subsides in a week or two and the involved cerebral tissue may largely regain its functional activities

On occasion thrombosis of the lateral sinus and of the posterior part of the longitudinal sinus may be remarkably "silent" The only sign may be the somewhat gradual onset of symptoms and signs of increased intracranial pressure, without evidence of localized cerebral dysfunction This situation compels ventriculography, which discloses a normal ventricular system and enlargement of the subarachnoid spaces over the brain surface Indeed, at the punctures for ventriculography the excess of fluid on the brain surface is often striking, and itself suggests the diagnosis This is *subacute external hydrocephalus* due to failure of absorption of the cerebro-spinal fluid into the thrombosed venous sinuses Many patients get well if lumbar puncture is repeated daily for ten days or thereby If this fails to meet the situation, bilateral subtemporal decompression provides the necessary temporary relief and the decompressions, full at first, soon subside, for the fluid circulation becomes re-established spontaneously

Cerebral abscess—The acute cerebral abscess, which is of the nature of an acute spreading septic encephalitis, is not susceptible to surgical treatment Surgical interference at this stage aggravates the situation All that can be done is to attempt to convert it to a subacute variety by chemotherapy

When the abscess attains a subacute state—that is when the infective process is of about seven days duration and the temperature has fallen—everything should be done to gain time The infective process is not yet walled off by a sufficiently strong layer of granulation tissue and direct interference should be avoided if possible If signs of increasing intracranial pressure are not too threatening masterly inactivity for several weeks is the best form of management If pressure signs should become ominous relief may be obtained by intravenous infusion of 30 c c of 50 per cent sucrose solution This acts very effectively in causing recession of œdema around an abscess and at this stage the volume of œdema is usually greater than that of the abscess Often the recession in œdema thus attained gives dramatic relief and it may be weeks before pressure signs become troublesome again If this treatment does not suffice a considerable area of bone at least 10 cm diameter should be removed over the site of the abscess The dura mater should not be opened on any account Free opening of the dura causes an abrupt distortion and vascular derangement of the œdematous brain which spreads the infection and ends fatally The intact dura will yield gradually and in a few days this will provide a large measure of additional space and corresponding relief Thus the abscess is coaxed on to a chronic state when direct intervention can be undertaken with good prospect of success At not less than three weeks, if possible and at not more than six weeks after the onset of its first symptoms the abscess may be drained This is done by minimal puncture of the dura mater the passage of an exploring cannula through the brain into the abscess cavity and the replacement of the cannula by a rubber catheter supported by a disc which lies on the scalp (Fig 240) Too deep insertion of the drain should be avoided lest the opposite wall of the cavity should be pierced It is convenient to inject a small quantity of thorotrast into the abscess and to occlude the drain for twenty four hours A thin deposit of radio-opaque thorotrast covers the abscess wall and remains there indefinitely By this means the collapse and final solid healing of the cavity can be observed by X rays Moreover if a second or a third abscess should form near the original one this development can be studied and localized by observing the corresponding displacement of the original shadow The thorotrast deposit has not interfered with sound healing in cases observed over several years When the abscess cavity has quite collapsed the drain is gradually shortened so that its track will heal solidly from the depths outward Drainage and shortening of the drain usually occupy three or four weeks Several abscesses developing in sequence may be successfully dealt with in this way When an abscess is more than three or four months old its wall becomes thick and it does not collapse completely if drained therefore it cannot heal soundly Such an old thick walled abscess is dealt with as a brain tumour and is very readily shelled out from the surrounding brain substance Sometimes after tapping an abscess variable local brain swelling persists and exploration with the cannula reveals the presence of multiple small abscess cavities In this circumstance the only prospect of success is the removal of the entire section of the brain affected This is often quite feasible without involving serious disability. The affected brain is "nursed" into a favourable phase by preliminary decompression and use of hypertonic solution as required. The diseased area is then widely exposed and resection is carried out.

Final cure of a suppurative cerebral lesion is often difficult to determine. The protein content of the cerebro-spinal fluid is usually considerably raised in the presence of a cerebral abscess. This should be ascertained during treatment, and return of the protein to normal should be verified later: this gives reasonable assurance that no "silent" abscess formation remains.

NURSING AND GENERAL MANAGEMENT

The head-injured patient, if conscious, is usually most comfortable with his head low. In the majority of post-concussional cases the cerebro-spinal fluid pressure is below normal. There is no reason to sit these patients up, nor to restrict their fluid intake as is sometimes advocated. In the few cases with a significant increase of intracranial pressure this factor should be dealt with locally by lumbar fluid drainage or by operation.

The case of uncomplicated concussion is usually able to sit up in bed without discomfort within three to seven days. When he can do so he is allowed out of bed. Gentle exercise is begun in a few days and rapidly advanced in controlled and graded stages until, in about six weeks, strenuous exercise can be well tolerated. In a majority of cases in which headache and giddiness are claimed to be disabling after six or eight weeks a complicating neurosis or previous disease such as migraine will be found responsible. In a minority, disturbances in regulation of the vascular supply of the cranium due to injury of the vessels or their controlling nervous mechanism is a cause of long-persisting headache. In this group the post-traumatic epilepsies often occur. Distinction and treatment of these conditions is the function of a somewhat specialized branch of neuro-psychiatry.

The patient who is unconscious after head injury should be laid on his side or in a half-prone position, so that his airway remains free and secretions can escape from his mouth. Fluid feeds should be given regularly and quite liberally by stomach tube. Bed-wetting should not be tolerated in the interests of the patient's skin, the nurses' labour and economy of bed linen. In male patients a length of wide colostomy tubing is affixed by adhesive strapping to the penis and allowed to drain into a receptacle at the bedside. For female patients the rubber bidette is most practicable. The bowel should be emptied by a "wash-out" on alternate days. These patients require close supervision, and pulse, respiration and temperature readings should be recorded hourly. Those in attendance should be instructed in what to look for as "danger signs" and in how to observe and record an epileptic fit. Elevation of temperature above 103° F. is treated by artificial cooling.

The stage of altered consciousness which follows post-traumatic unconsciousness exhibits many different phases varying in degree and in manifestations. It varies from mild disorientation or confusion to acute post-traumatic psychosis often accompanied by vivid and alarming hallucinations. It is obviously most desirable that these irritable restless and noisy patients should be segregated in single rooms They require the whole-time attention of a nurse The patient s restless movements should be so guided as to avoid harm to himself or others Forcible restraint is to be avoided If restlessness is such as to entail undue exhaustion it should be controlled with sedatives of which morphia and hyoscine and paraldehyde are the most generally useful The nurse should understand the characteristics of dysphasia and dyspraxia so that she can manage patients so afflicted with sympathetic intelligence and report observations of diagnostic value

The after care and rehabilitation of patients who have sustained cerebral injury involves frequent neurological psychological and often psychiatric assessment It should be remembered that on the average the neural mechanisms which subserve mental activities suffer more than those concerned with physical activities For rehabilitation a well integrated team is necessary comprising neurologists psychologists and psychiatrists with experts in physical re-educative technique in speech training and other psychologic re-educative measures and in occupational therapy in which both these measures are combined A close liaison with the Ministry of Labour employment organizations and with Military re-training depots is requisite for successful completion of the task in hand That task to which all the activities mentioned in this chapter are devoted is the return of the patient to his previous job or failing that to the most useful occupation of which he is capable

Of the many disabilities which may follow craniocerebral injuries post-traumatic epilepsy is important Its nature pathology diagnosis and management pass beyond the scope of this chapter

CHAPTER XXX

WOUNDS OF THE FACE AND JAWS

WOUNDS of the face differ from wounds elsewhere in that their effects cannot well be hidden The chief aim in their treatment is to restore function and reduce disfigurement to a minimum

The surgeon who contended with facial injuries during the 1914-18 war had little to guide him and much of his work was necessarily experimental, to-day he is in a position to take up the task armed with well-founded principles which have stood the test of twenty years' application There can be little doubt that this work calls for special training, and for that reason Maxillo-Facial centres have been established It is realized however, that many facial injuries do not call for special treatment, while others may not require it or by reason of circumstances cannot obtain it until the later stages of their treatment

The object of this chapter, then, is threefold —

1 To outline treatment, which in many cases will be all that is required
2 To ensure, in more severe injuries, that nothing will be done to jeopardize the chances of obtaining a good final result while making certain that everything possible is done to pave the way for later reconstruction
3 To indicate briefly the main types of reconstruction

Classification—In order to develop a satisfactory classification it is necessary to visualize the face and jaws as composed of three main elements —

(*a*) Covering
(*b*) Supporting (skeletal) tissue
(*c*) Lining membrane

A wound may affect one, two, or all of these elements In each instance the extent of the tissue loss is the most important factor from the point of view of treatment

WOUNDS INVOLVING COVERING ONLY

Wounds belonging to this category have formed a high proportion of the injuries resulting from aerial bombardment They should receive attention at the earliest possible moment, and since their treatment forms the basis of all facial injury treatment it will be discussed in detail

Anæsthesia—Occasionally, as in cuts from broken glass, treatment can be carried out satisfactorily under local anæsthesia the solution being injected well away from and not into the wound As a rule a general anæsthetic should be administered preferably by the intratracheal route

Preparation of the skin should not be attempted until the patient is fully anæsthetized and the anæsthetist is in a position to relegate the whole face to the surgeon The entire face should be cleansed with soap and water followed by a watery antiseptic solution Metaphen merthiolate biniodide of mercury dettol are all suitable for this purpose Metaphen (1 2 500) is particularly valuable in the eye region and in the neighbourhood of sensitive mucous surfaces Turpentine or ether may be used for the removal of grease or oil In the region of the eyebrow remaining hairs provide the only guide to alignment and should not be removed by shaving they are cut short to avoid interference with sutures and the risk of including hair in the wound The same rule applies when wounds cross the scalp hair line the scalp region should be shaved, but a few rows of hair cut short should be left to indicate the line of junction of hairy and non hairy skin Elsewhere hair in the neighbourhood of a wound should be shaved not merely for surgical cleanliness but to facilitate the later fixation of dressings

Isolating the field of operation—After this general skin preparation the surgeon attends to his own toilet and then drapes the patient Head towels are applied and the rest of the body is covered. Hand kerchiefs or pieces of butter muslin fixed to the surrounding skin by mastisol provide the most satisfactory means of shutting off the wound area towels fixed by clips cannot be persuaded to lie snugly over the ups and downs of facial contour

Cleansing and exploring the wound—It must be understood that *routine wound excision has no place in facial surgery* That same copious blood supply which in face wounds is often responsible for profuse and even dangerous hæmorrhage will often ensure the viability of flaps almost completely detached and is responsible for the rarity of serious spreading infection Gas gangrene is unknown

Peroxide of hydrogen is used to loosen adherent blood clot and then the wound is irrigated with normal saline solution Both solutions may be applied where the situation allows by Higginson or dental chip syringe thus providing the added advantages of forceful irrigation

With the help of good illumination and efficient suction or swabbing a careful search is made for foreign material Preliminary X ray examination will have shown metallic foreign bodies and these must be accounted for carefully it must be remembered that the removal of fragments of glass wood and clothing seldom demonstrated in a radiograph is equally important In this search the wound should be opened up to its full extent for many wounds without skin loss and having a very trivial appearance are of deep shelving character Actual scrubbing with a tooth brush or small nail brush is the only satisfactory way of removing ingrained dirt from the wound and the surrounding skin Ragged bruised or crushed skin tags should be trimmed away with sharp eye-scissors

Hæmostasis is most important An occasional large vessel will call for ligature but most bleeding points can be controlled by torsion, and the

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Anæsthesia—Occasionally, as in cuts from broken glass, treatment can in paraffin as at the London Hospital are cheaper and make good substitutes It is probably important that skin sutures should be impermeable to tissue fluids and preference should be given to materials which tend to set stiffly in square form and so splint the skin edges rather than to those softer materials which tend to form a circular loop

Correct alignment and accurate approximation of wound edges call again for good lighting and efficient suction Where the latter is not available the assistant must keep the skin edges clearly visible by repeated gentle wiping with a dripping wet swab

It is best to introduce a few widely separated sutures first bringing obviously corresponding points together and then to proceed to the more meticulous approximation of skin edges Interrupted sutures are preferred because individual ones can be removed without gaping of the whole length of the wound should evacuation of hæmatoma or pus be required The vertical or end-on mattress suture gives admirable approximation of deeper layers while ensuring proper eversion of skin edges In face wounds both the *near* and *far* points must be kept close to the skin margins In its continuous form this stitch makes an ideal apposition suture when conditions allow of its employment The figure-of-eight suture provides a valuable means of obtaining full deep-tissue approximation without buried suture material Care should be taken to avoid strangulating the tissues held in the loop of any stitch the knot should be drawn just taut and there should be no blanching of the skin

Drainage of the wound—A fine drain to allow escape of blood provides a sound insurance against hæmatoma formation Four to six strands of medium silkworm gut twisted together serve the purpose well, and when removed in twenty four to forty-eight hours leave no unsightly depression in the suture line Before the dressing is applied a gauze swab is rolled along the wound to express all blood

Dressings—Dressings on face wounds should be kept as small as possible There is no indication for covering more than the suture line and any adjacent undermined areas The commonly seen application of large dressings and copious bandage represents gross waste of material and usually gives discomfort to the patient Further the small dressing allows of near fixation and contributes largely to the efficiency of the pressure obtained It is an advantage too to have the neighbouring skin areas under observation for signs of inflammation or hæmatoma formation.

Uniform pressure is best obtained by applying multiple strips of narrow strapping over a pressure pad of dry gauze Ribbon gauze open wove bandage or lastonet spread evenly over the pad and fixed to surrounding skin by mastisol or collodion is equally effective In some situations excellent splinting of the wound can be provided by applying several layers of such material soaked in collodion, a type of fixation particularly useful in the cheek region for it restricts movement in a very mobile part The silkworm gut drain may be placed with its free end projecting so that it can be removed without disturbing the dressing A larger gauze and wool dressing held by a crêpe bandage may be applied in addition, and retained until the period of post anæsthetic restlessness is over

Removal of sutures and after treatment—In the absence of pain pyrexia burying of catgut in the wound should be avoided as far as possible Diathermy coagulation offers many advantages in this connection

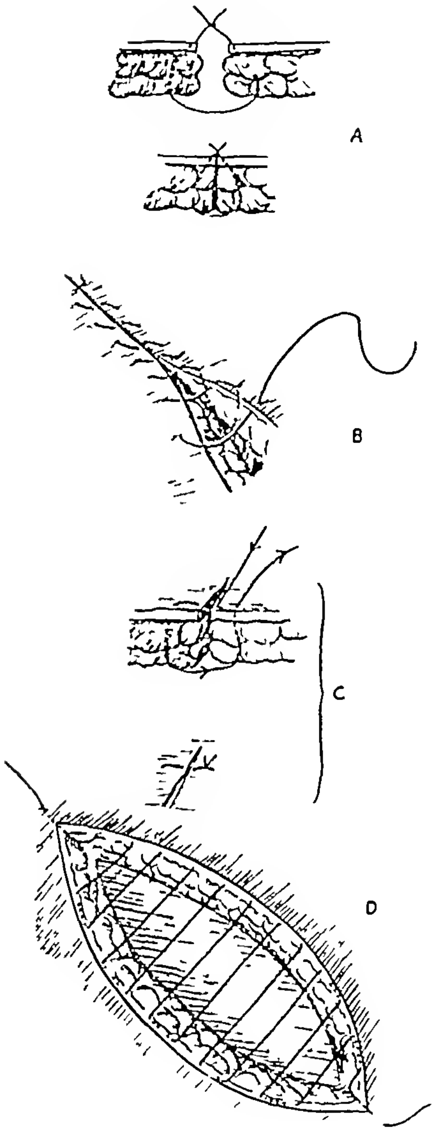


FIG 241
Methods of suturing

A, Interrupted suture taking full bite of deep tissues but entering and emerging close to the skin edge A suture of this type gives broad wound edge approximation with a minimal risk of stitch scarring

B, Continuous end on or vertical mattress suture This gives broad wound edge approximation and ensures accurate apposition of skin edges without inversion

C, Interrupted end-on or vertical mattress suture

D, Subcuticular or intradermal suture

The wound is now mechanically clean and a decision must be made about its repair Gross contamination and extensive contusion of surrounding skin are contra-indications to immediate closure, more particularly when the case is seen late In these circumstances the wound is packed lightly with gauze soaked in eusol, flavine solution (1 1,000) or normal saline Thorough impregnation of the wound surface with sulphanilamide powder has done much to reduce infection Dressings are not disturbed for forty-eight hours, when, if signs of infection are absent, the wound edges are approximated by sutures Wounds which are not grossly contaminated and which are seen soon after infliction may be considered eligible for primary suture It is difficult to formulate a rule in this connection, but it may be stated that it is usually justifiable to attempt primary closure up to eighteen hours from the time of injury

Technique of suturing facial wounds—Sutures should be placed as near as possible to the skin edges, but this need not prevent them obtaining a good " bite " of the deeper layer of the wound margin (Fig 241) It should always be borne in mind that the scar line may call for subsequent excision The excision of a disfiguring scar line, however broad, depressed or elevated it may be, is a comparatively simple procedure The bane of the plastic surgeon is a scar line crossed by numerous transverse stitch scars produced by widely placed sutures, often of coarse material and left in position much too long, necessitating as it does wide removal of skin which can be ill spared

Fine needles (eye, curved, 6 or 3) and fine suture material should be employed No suture material is quite so satisfactory as ophthalmic silkworm gut, but Kaldermic (Davis and Geck) and Nylon sutures are more uniform in thickness and tensile strength than much of the silkworm gut now on the market All may be obtained ready-mounted on eyeless needles in tubes Deknatel silk and silk prepared a wound of this type will present within ten to fourteen days a clean granulating surface suitable for skin grafting

In many cases the result given by primary or secondary Thiersch grafting is after a course of grease massage satisfactory in others the cosmetic result is poor and replacement by free full thickness graft (Wolfe), by local rotation or transposition flap (Fig 242) or by skin brought from a distance by pedicled flap (Fig 243) or in tubed pedicle form (Fig 244) is indicated

FIG 242

G.S.W upper lip with extensive loss of skin Replacement by simple transposed flap from submandibular region.

FIG 243

G.S.W infra-orbital region with loss of skin. Spontaneous slow healing produced dense keloid scar seriously restricting eyelid movements. Scar excised, eyelids released and raw surface (corresponding to original skin loss) covered by pedicled flap from forehead.

Colour texture and thickness of the implant and also the absence or presence of hair call for consideration Flaps from the immediate vicinity are ideal but unless the defect is small are liable to cause secondary distortion The forehead flap provides skin of good match for other parts of the face but leaves behind it scars which may be difficult to hide The tubed pedicle flap is most useful when subcutaneous tissue in addition to skin is required. The Wolfe graft gives excellent results in situations where uniform pressure dressing can be maintained but sometimes takes on a brownish tinge or remains unpleasantly white or swelling, and if gentle pressure over the dressing elicits no undue tenderness, nothing is disturbed until the third day, when alternate sutures are removed If the wound edges are obviously firmly united, the remaining sutures are removed straight away, but if there is any doubt on this point or if there is reason to expect early pull on the newly formed scar line, it is wiser to leave them undisturbed for another two days As a half-way measure, sutures showing any tendency to "cut in" may be divided but left *in situ*, their buried parts still splinting the wound edges Good lighting, fine scissors with thin and sharp-ended blades cutting right up to their points, and fine non-toothed forceps are essential for satisfactory removal of sutures Each suture should be examined as it is taken out and there must be no doubt about the completeness of its removal

Immediately after the removal of sutures a strip of ribbon gauze soaked in collodion is applied This acts as a splint and prevents early broadening of the scar line Such a final dressing may be left undisturbed until it loosens spontaneously, or may be removed in three to four days after softening with acetone I do not recommend leaving newly sutured face wounds without dressings, for this almost always leads to mild infection of suture points which then remain obvious for some time after the wound itself is soundly healed

Gentle rotatory massage with a finger greased with lanolin cream, commenced ten to fourteen days after operation aids absorption of any deep thickening and keeps the skin scar free of adhesions If there is a tendency to keloidal thickening, X-ray or radium treatment should be given immediately When keloid scars are excised this treatment is given before and after operation

WOUNDS WITH SKIN LOSS

When there is skin loss the problem is a more difficult one Those parts of the wound which can be closed by simple approximation should be sutured No attempt should be made to drag edges together by sutures under tension, and no undermining of the skin to facilitate closure is justifiable Any skin torn up in flap form should be replaced in correct position, and when marginal fixation is impossible may be anchored by a few mattress sutures holding it to the deep tissues A decision must now be made about the treatment of the remaining raw surface If the wound is a fresh one and not grossly contaminated it may be covered immediately by a Thiersch graft applied with careful attention to pressure dressing So far as I am aware, this procedure was never carried out in the last war, and no case suitable for such treatment has yet come my way in this There is every reason to believe, however, that in the majority of cases the graft will take without complications (for skin is the ideal dressing for any raw surface), and many painful dressings and a long period of healing will be avoided

In older wounds a layer of tulle gras is applied, and covered by dressings of the type already recommended for open wounds Dressings should be changed as infrequently as possible, for there is no doubt that repeated exposure increases risk of infection, more particularly in crowded wards where cross infection is so common In the absence of superadded infection which deserves special mention, a shelving wound from in front of or from behind the ear, close to the skull, which, while not completely severing the pinna, divides the external auditory meatus The damage to the meatus is frequently overlooked and the passage may become completely

FIG 215

Laceration of upper eyelid healed, after indifferent suturing, with considerable deformity Scar excised and wound, thus reproduced, carefully sutured in layers An equally good result should follow careful primary suture of such wounds

obliterated by scar tissue In such cases, given good lighting and suction, it is always possible to introduce sutures, either by a small half-circle or Reverdin needle, to approximate skin edges and so promote rapid, clean healing and prevent stenosis A short rubber tube, suitably anchored externally, or a greased gauze plug may be introduced into the meatus with advantage

INJURIES INVOLVING SKELETAL TISSUES ONLY

Into this class fall all the numerous cases of fracture without material damage to covering or lining In the treatment of air-raid casualties many of these will be overlooked, but every effort should be made to diagnose and treat them before the deformity they necessarily produce becomes an established one No surgeon would dream of leaving a fracture of a limb bone unset yet fractures of the nasal and malar bones regularly go untreated Fractures of the mandible and maxilla which give immediate interference with function are less liable to be overlooked

Fractures of the nose are diagnosed less on radiographic than on clinical evidence A bridge line seriously deviated to one side accompanied by bleeding from the nose is obvious evidence of fracture and displacement of the nasal bones If displacement is not gross and if the case is not seen until swelling masks the deformity diagnosis may not be so simple and it may be wise to defer operative interference until the disappearance of swelling renders the deformity more obvious and the diagnosis correspondingly more certain. Occasionally undue mobility can be elicited by gentle digital manipulation but crepitus is seldom felt X ray examination should confirm the diagnosis and even if the radiograph fails to show lateral fracture lines it will clearly demonstrate those transverse fractures commonly associated with a depressed lower fragment Consolidation of nasal fractures is seldom complete before the third week after injury and up to this time mobilization is usually possible

The disimpaction and setting of a recently fractured nose is a short and simple matter but if it is to be accomplished with precision and certainty a full intratracheal anæsthetic with proper packing of the pharynx is required Fig 240 illustrates almost better than words the technique employed. If the nasal bones have been thoroughly mobilized and if at the operation it has been possible to displace the bridge line to the side away from that of the original deviation there is seldom any tendency for the deviation to recur The patient is shown how to keep the bridge line straight by digital manipulation and may be discharged at a very early date

Fig 240
Disimpaction and setting of fracture of the nose by Walsham s forceps.

Older fractures call for more extensive and difficult treatment The fracture lines must be reproduced by chisel or saw cuts made via intranasal incisions along the lines of junction of nasal processes and maxillæ and sometimes by additional separation of the septum on each side before manipulation can correct the deformity In old fractures with established gross deformity it is necessary to excise a triangle of bone apex upwards on the side away from the deviation before correction can be obtained.

In severe nasal fractures and more particularly in those associated with fractures of the maxillæ some degree of depression of the bridge line persists Contour may be restored by the introduction of a free graft of cartilage or bone (Fig 247)

Fractures of the malar zygomatic region are more commonly overlooked (Fig 248) than any other fracture in the face region This is to be regretted since their treatment shortly after injury is a very simple and short procedure, while if left uncorrected, the deformity, which becomes steadily more obvious as swelling subsides, is a very disfiguring one

Fig 247

Diagrams illustrating the use of a hinged cartilage graft to define and build forward the bridge line of the nose

The bone is usually separated from its normal attachments at the fronto-malar synostosis, the junction of inner and middle thirds of the infra orbital margin and in the zygomatic arch It is commonly driven downwards and forwards into the maxilla where it becomes impacted The antrum is almost invariably damaged, and this causes unilateral bleeding from the nose The floor of the orbit is depressed and there is commonly subconjunctival hæmorrhage and some degree of diplopia Damage to the infra orbital nerve produces numbness of the cheek and upper lip and of the corresponding upper teeth while later there may be pain of a neuralgic character in this area The space between the zygomatic arch and the maxilla and temporal bone is so reduced that movements of the coronoid process and temporal muscle are restricted and the patient is unable to open the mouth to full gape Radiographs of the skull (Fig. 249) taken in the occipito-mental occipito frontal and 30° fronto-occipital positions are needed to demonstrate the various fracture lines

Fig 48

Depressed fracture of the malar bone The right pupil is nearly half an inch below the level of the left, and the lower eyelid margin and inner canthus are correspondingly depressed. The bony bridge of the nose is pushed over to the left and there is loss of malar eminence.

Disimpaction and elevation (Fig 250) are achieved by the introduction of a lever (Fig 251) deep to the temporal fascia along the surface of the temporal muscle from a short incision in the hairy scalp to a position deep to the zygomatic arch Leverage upwards and outwards is accompanied by a convincing grating and click as the bone assumes its correct position.

In old uncorrected fractures a choice has to be made between freeing the bone by chisel cuts and camouflaging of the deformity by the introduction of fat cartilage or bone graft to build up the contour When symptoms are absent and only disfigurement has to be considered the latter is probably the wiser choice but when displacement is extreme and there is serious interference with mandibular movements the bone should be freed and replaced In these circumstances the bone will seldom stay in

Fig 249

Radiograph showing fracture-displacement of right malar bone.

FIG 250
Elevation of the malar bone by lever passed deep to the zygoma through a short temporal incision

corrected position without some form of fixation A fine wire suture passed through holes drilled on each side of the fracture in the fronto-malar region is sometimes sufficient in other cases the antrum must be opened from the mouth and the bone kept in position by packing of this cavity When cosmetic treatment by fat or cartilage graft is undertaken for restoration of contour in the infra-orbital and malar regions, it is possible to introduce a sufficient quantity of the grafting material under the periosteum of the floor of the orbit to correct the level of the globe

Fractures of the mandible—It is impossible in this contribution to discuss in full the treatment of fractures of this bone nor is this necessary, for the surgeon should always refer his cases at the earliest possible moment to his dental colleague Certain general points may, however, be mentioned When teeth are present in both jaws an undamaged upper jaw provides the best possible splinting mechanism for a fractured lower jaw. Reduction of the fracture and maintenance of the teeth in correct occlusion until union has occurred are the essential aims of all treatment Inter-dental wiring (Fig 252) is, in my opinion, the best temporary method of attaining this object and, in the simpler fractures may be all that is required In most cases, however, and in all those with multiple fractures completely separating a portion of the horizontal ramus, some form of metal cap splint is advisable Figs. 253 and 254 illustrate the types of splint evolved during and after the last war and regularly employed by my colleague, Mr A L. Fraser, at Queen Mary's Hospital (Ministry of Pensions), Roehampton.

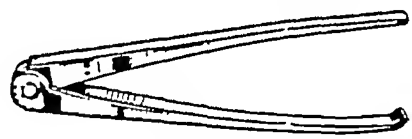
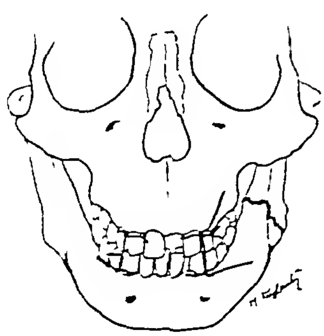


FIG 251
Kilner's malar lever



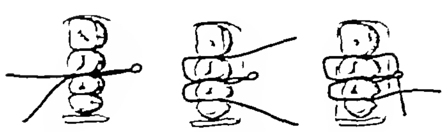


FIG 252
Eyelet method of interdental wiring.

The dotted lines in Fig 254 indicate the position in which a bar may be introduced between the two parts of the lower splint This strengthens fixation and allows the upper and lower splints to be separated early for the encouragement of mandibular movements

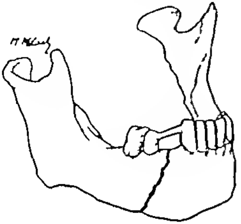


Fig. 231

Metal cap splint for simple fracture of mandible

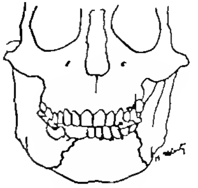


Fig 234

Metal cap splints for upper and lower teeth bolted together in correct occlusion in use on bilateral fracture of body of mandible

In edentulous cases the vulcanite double Gunning splint is used (Fig 233) Fig 236 illustrates the splint employed in cases of bone loss It places the fragments in correct occlusal position and defines the gap to be filled by bone graft (see p 312)

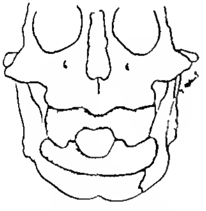


Fig 233

Double Gunning splint used for fracture of edentulous mandible.

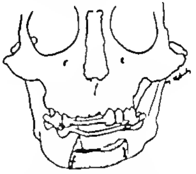


Fig 236

Splint similar in construction to that shown in Fig 233 employed for fracture of mandible with loss of bone The splint holds the fragments in correct occlusion and thus defines the gap to be filled by bone graft.

Mention should be made of the value of the patient's own denture for stabilizing a fracture in an edentulous mandible and of the method of circumferential wiring over a denture or a specially prepared base plate When other means are not available recourse may be had to some form of external fixation. In the *Lancet* of 4th October 1941 L Pohl described hook-screws for this purpose while R Mowlem and others illustrated an ingenious adaptation of the Roger Anderson two pin method used in the control of fractures of long bones

Teeth in or adjacent to lines of fracture should be extracted, together with any unhealthy teeth in the jaw. Few fractures of the mandible are strictly "closed" fractures; they are usually "open" on the mouth side and are therefore liable to become infected. The removal of teeth reduces this risk of infection, but a careful watch must be kept for abscess formation near the lower border of the jaw, and dependent external drainage must be provided immediately this occurs. It has been suggested that "prophylactic" incision should be made in this region, but this appears unnecessary.

Much discussion has centred on the short edentulous posterior fragment, and numerous suggestions have been put forward for its control. In the absence of bone loss the average posterior fragment of this type seldom becomes displaced. When the parts are placed at rest by fixation of the larger fragment in correct position, the posterior fragment usually falls into natural position and is locked end-to-end with the anterior fragment. Occasionally, however, and more particularly in fractures produced accidentally during the extraction of a lower wisdom tooth, the fracture line runs more or less horizontally and leaves the posterior fragment completely uncontrolled, pulled upwards and inwards by the muscles attached to it. In such cases all forms of saddle extension from the intra oral splint have proved unsatisfactory, and the modern tendency is towards external control by a wire passed through a drill hole in the angle region and connected by elastic traction band to a plaster of Paris head cast, or to an extra oral prolongation from a cap splint cemented to teeth on the larger fragment (Fry).

Minimal exposure of the fracture line along the lower (or posterior) border of the bone and the insertion of a fine wire suture between the fragments achieves the same object. It must be constantly remembered that the fracture line is potentially infected from the mouth and that this infection may spread down to the site of wiring. If the exposure is minimal and the bone grasped in the wire suture is small, this complication cannot be considered a serious one, provided free drainage is established immediately. The wire need not be removed, but the small wound must be kept open and under constant and careful observation.

When there is loss of bone of ½ in. or more in a fracture of this type, an ideal end-result demands a bone graft, and there need therefore be no anxiety about the temporary displacement of the posterior fragment. Before the technique of mandibular bone grafting had been perfected, every effort was made to allow such a posterior fragment to come forward into contact with the other fragment and so ensure union. Upper molar teeth were extracted to facilitate this. The results so far as union was concerned were often good, but it must be obvious that union achieved in this manner was always mal-union and could not be expected to give perfect functional results.

Fractures in the region of the condylar neck are treated by fixing the jaws in occlusion. This places the muscles at rest, and the small uncontrolled fragment will often fall into good position. I have never found it necessary to remove such a fragment, and no difficulty has been experienced in obtaining a full functional gape within a few days of the removal of splints, even after six weeks' fixation.

In all fracture cases careful oral toilet throughout the period of treatment plays an important rôle.

It should be mentioned that there are those who advocate fixation in the open-bite position for the treatment of jaw fractures, advancing as arguments in its favour that it makes after-treatment easier, diminishes danger from post anæsthetic vomiting, facilitates feeding, relaxes pull by the hyo-mandibular muscles on a separated central fragment and prevents post operative trismus. The technique was given a trial by my dental colleagues during the last war, but was abandoned early in favour of the closed bite position, and as this has given most satisfactory results and no trouble on the counts mentioned, it has remained the method of choice in the continuation of post-war work at Queen Mary's Hospital, Roehampton, and in most civilian clinics elsewhere. The expert anæsthetist experiences no difficulty when called upon to anæsthetize a patient with fixed splints, for the position actually facilitates "blind" intubation via the nose.

Fractures of the maxilla—No detailed classification of fractures of this portion of the facial skeleton will be attempted. They readily divide themselves into those which involve the tooth-bearing portions of the bone and those which do not.

Fractures involving only the alveolar parts of the maxillæ are essentially dental problems as are also those horizontal fractures at a somewhat higher level which separate alveolar and palatal parts from the rest of the bone In these treatment aims at freeing the separated bone setting it in correct position and retaining it in that position by suitable splinting until union occurs The final test of success is the restoration of correct occlusion of teeth Spread of infection along fracture lines is less common in maxillary than in mandibular injuries for dependent drainage occurs spontaneously it is wise nevertheless to remove all doubtful teeth and certainly any whose roots communicate with or are adjacent to the fracture lines

As a temporary measure when both jaws bear teeth the undamaged lower jaw may be employed to splint the fractured upper jaw the teeth being brought into occlusion and held in that position by any form of fixation which prevents the patient from opening his mouth. In most cases, however some form of cap splint maintaining upward pull from Kingsley's extra-oral extensions (Fig 257) to a well fitting head cap is employed When there is a tendency for the fragment to become displaced backwards forward traction is provided by bands attached to wire pro jections coming down in front of the mouth from the head cast

Fig 257

Fracture of the maxilla treated by an upper dental plate with Kingsley's extra-oral arms and elastic traction to head band.

Other fractures in the maxillary region call only for local treatment Fractures of the malar zygomatic compound which involve the malar process of the bone and cause damage to the antrum have already been discussed Fractures of the nasal processes have been considered in the discussion of fractures of the nose (see p 297) That portion of the maxilla lying between these parts frequently remains un damaged and firmly fixed, but occasionally from the effects of direct violence its anterior wall may be driven backwards This type of displacement in common with fracture displacements of the malar-zygomatic usually involves disturbance of the floor of the orbit and unless corrected may be responsible for troublesome diplopia and disturbance of eye movements The only satisfactory treatment consists of opening the antrum through the mouth (as in the Caldwell Luc operation for antral disease) and manipulating the fragments into correct position by finger or lever Retention in good position is often difficult but careful packing of the antral cavity over a period of fourteen to twenty-one days is usually successful.

There remain those cases in which both maxillæ are driven bodily back wards by excessive direct force from in front In these thorough mobiliza tion and disimpaction followed by splinting on the lines already mentioned for fractures of the lower parts of the bones, is infinitely preferable to gradual reduction by elastic traction and will do much to prevent the "dish-face" deformity characteristic of this type of injury

In multiple fractures in the maxillary region, it is wise to trace carefully all lines of fracture by a series of radiographs and by thorough clinical

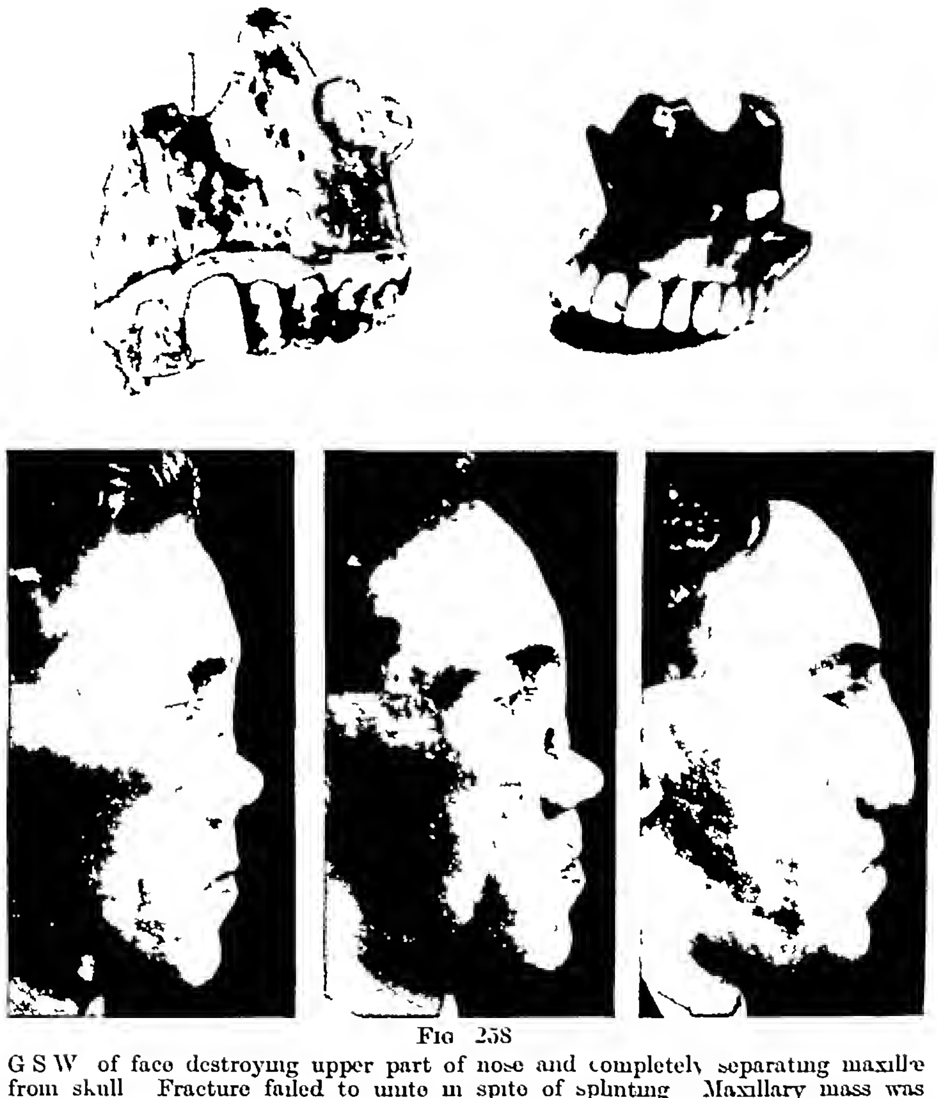


FIG 258

G S W of face destroying upper part of nose and completely separating maxillæ from skull Fracture failed to unite in spite of splinting Maxillary mass was enucleated and replaced by denture of hollow-box construction The enucleated bone and the denture which replaced it are shown and also the stages in the reconstruction of the nose

examination Stereoscopic radiographs are particularly valuable in this investigation In most cases some part of the maxillary skeleton will be found to retain its normal attachment to the skull Working from this as a fixed point it should be possible, with expert dental collaboration, to link up the displaced lower parts (after disimpaction and mobilization) and so provide a foundation below on which to support the parts above

In exceptional cases the whole maxillary mass of bone remains separated and refuses to unite In these the bone may be completely enucleated and the cavity filled immediately by a Stent mould covered in those parts destined to come in contact with raw surfaces, by a Thiersch graft This mould is replaced at an early date by a dental prosthesis of hollow box construction in order to fill the defect caused by the missing maxilla (Fig 258)

Fractures of both maxilla and mandible—When fractures of both upper and lower jaws are present difficult but not insuperable problems are presented. The maxilla is first stabilized on the lines already described and the fragments of the mandible are then brought into correct relationship with it Alternatively restoration of correct occlusion being the chief aim of treatment the upper and lower teeth may be linked together in correct position by splints before any attempt is made to re-establish the maxillary attachments to the skull by traction on extra-oral extensions to head band or cast Even when teeth are present in both jaws treatment is difficult enough when both are edentulous the dental surgeon is called upon for a full display of ingenuity

INJURIES INVOLVING SKELETAL TISSUES AND LINING

Completely separated bone fragments should be removed but any retaining firm attachment to muco-periosteum should be left undisturbed Fractures are suitably splinted and mucosal wounds are sutured with care to avoid obliteration of gingival sulci When skeletal tissue in the maxillary region is destroyed immediate support to prevent contraction and deformity should be provided by Stent mould covered if necessary by Thiersch graft and replaced later by dental prosthesis

INJURIES INVOLVING SKELETAL TISSUES AND COVERING

These range from contusion or abrasion of the skin associated with simple fractures to extensive skin loss with severe comminution of underlying bone In the jaw regions the latter condition is usually associated with a defect in lining and complicated by bone infection Treatment consists of removal of foreign bodies and separated bone fragments splinting of fractures and repair of the external wound on the lines already indicated

Through-and through wounds grooving bone and scattering fragments in the track should be treated conservatively They frequently heal without complications but if infection occurs free drainage should be established and loose bone fragments removed

INJURIES INVOLVING COVERING LINING AND SKELETAL TISSUES

The majority of serious gunshot wounds fall into this group Treatment of skeletal damage differs in no way from that already outlined It is essential as in less severe injuries to place all viable bone fragments in correct position and retain them thus until union has occurred.

In most cases there is extensive loss of lining or covering or both and all must be considered infected from the start No attempt should be made to close the defect by dragging skin or mucosal edges together under tension. The chief indication is to cover raw bone surfaces as far as possible and this is best achieved by sewing lining to covering around the margins of the defect. This procedure minimizes bone infection and at the same time gives early and clean healing without deformity of neighbouring parts The formation of those dense scar masses which so frequently necessitated

Fig 259

G S W lower lip and chin Reconstruction by inturned local flaps for lining and a double pedicled forehead flap for covering The forehead defect was covered by a free full thickness skin graft Later a curved bone graft was successfully implanted between the molar "stumps" of the mandible and subsequently "buccal inlay" in front of this restored the gingival sulcus and allowed a denture to be worn

a separate stage of operation in the cases of the 1914-18 war is avoided, and viable marginal flaps are made available which can be turned in to line the defect later Dressings are simpler and less painful, and openings into the mouth can be readily "plugged"

Figs 259-264 may be taken as illustrative of fairly typical wounds in this group, while Fig 265, presenting a case from civilian practice, has been chosen to illustrate repair of a more extensive loss in the cheek region

Accurate diagnosis must be made of the size and shape of lost tissue in each of the three elements and plans made for replacement as far as possible *in kind* Mucous membrane not usually available in sufficient quantity to shift in flap form is commonly replaced by skin except in the

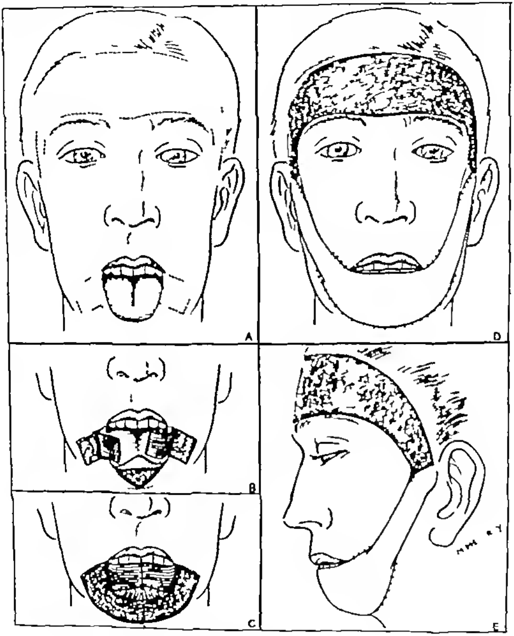


Fig 260

Drawings illustrating the reconstruction carried out in the case shown in Fig 259

restoration of the red margin of the lip It has been employed in selected positions in free graft form, but it is very doubtful whether it possesses any advantages over the more certain and more commonly used Thiersch graft Whenever skin is used in this way to replace mucosa it should be borne in mind that unless the graft is cut thin (as nearly epidermal as possible) and this is best achieved by sewing lining to covering around the margins of the defect. This procedure minimizes bone infection and at the same time gives early and clean healing without deformity of neighbouring parts The formation of those dense scar masses which so frequently necessitated

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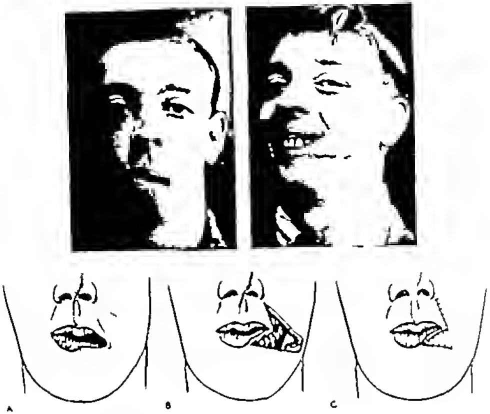


A B C

FIG. [illegible]

G.S.W. lower lip with loss of all tissues. Scar freed from bone by "buccal inlay" and lost tissue replaced by full thickness flap transposed from above to below angle of mouth

FIG. 263

G.S.W. of cheek with loss of all thicknesses, treated by suture of mucous membrane to skin around the defect. Reconstruction by inturned marginal skin flaps for lining and transposition flap from submandibular region for covering.

and preferably from a hairless area, it may grow hair In time past many grafts implanted in the mouth produced magnificent intra-oral beards

The method of preliminary lining of a flap, destined to supply covering, by either Thiersch or Wolfe graft is obviously economical of time and

Fig 261

G S W chin and lower lip with extensive loss of all tissues Alternative method of reconstruction tubed pedicle flap from neck providing both lining and covering Bone graft and "buccal inlay" were carried out as in the case illustrated in Fig 259

secondary scarring Various methods of folding the terminal parts of the flap are available for the same purpose, but there is much to be said in favour of independent lining and covering flaps, each of which possesses ample intrinsic blood supply and need not rely on early vascularization from the

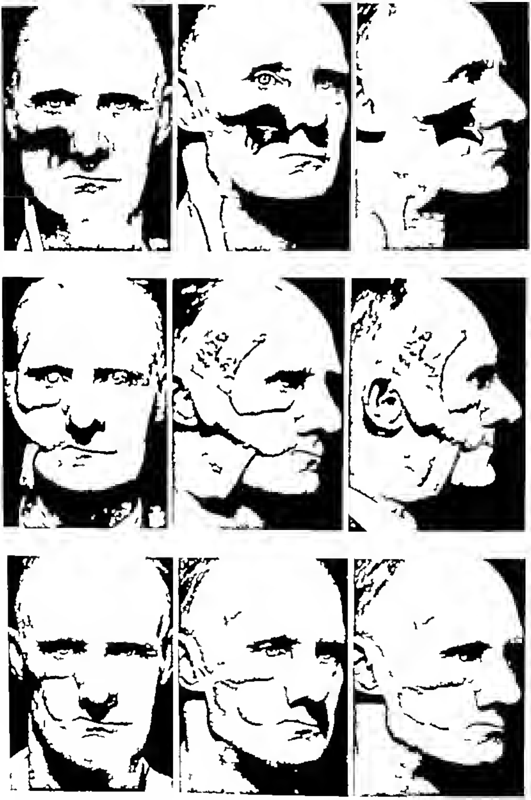


FIG 65

A record taken from civilian practice illustrating the repair of a large defect in the cheek by neck tubed pedicle flap for lining and forehead flap for covering The defect on the forehead has been covered by a thick Thiersch graft.

margins of the defect Further, the flap whose deep surface has been covered by a free skin graft always tends to contract and thicken, and it is never easy to obtain early and sound union between the lining margin of the defect and the freshened edges of the graft

Mention has already been made of the usefulness of flaps from the skin surrounding the defect turned in to supply lining These are often employed even though they are hairy, and if carefully planned give the opportunity

FIG 264

G S W of cheek and upper lip with extensive loss of tissue Marginal suture of mucosa to skin was not employed and considerable deformity resulted A tubed pedicle flap was prepared on the neck and at the same operation all scar was excised and mucosa-to-skin suture carried out Photographs show stages of transfer of flap to provide both lining and covering for the defect

of avoiding superimposition of the suture lines of lining and covering No attempt at epilation by X-rays is justifiable, for if used in sufficient dosage to destroy hair permanently, X-rays always damage the blood supply of the skin Once the soft parts have been restored, any hair-bearing skin inside the mouth can be excised and replaced by Thiersch graft at a stage when contraction can be controlled, as in the well-known buccal inlay procedure The illustrations already referred to indicate various forms of covering flap

Collaboration with the dental surgeon during the stage of repair of soft parts will produce various intra-oral appliances to help support the newly implanted tissues

When lining and covering have been successfully supplied, the skeletal fragment At the bone graft operation it is readily located freed from scar tissue adhesions and brought into correct position before the graft is inserted The major fragment being held in correct position by splint the graft supplies correct proportions in the angle region and sound function

Fig 267

Mine explosion wound of face with extensive loss of mandibular bone After repair of soft tissues a bone graft from the iliac crest was inserted which restored normal contour and function. A splint similar to that shown in Fig. 630 was employed to hold the teeth in correct occlusion. The second skiagram shows the patient wearing dentures.

is restored An undamaged temporo-mandibular joint never gives trouble during this manœuvre and full movement is invariably possible within a few days of removal of the splints Splints are usually retained for six to eight weeks X ray examination is helpful in judging the progress of bone consolidation but clinical union of the graft is frequently present some weeks before this is demonstrable in a skiagram loss should receive attention, but nothing further should be attempted until the soft tissues have been rendered supple by massage and a sufficient period has been allowed to elapse to avoid the risk of lighting up latent infection Three months may be considered a minimum period for this, but longer should be given whenever possible

SKELETAL DEFECTS

Bone grafting of the mandible—The main indications for bone grafting in the mandibular region are (1) non-union resulting from bone loss, initial or due to sequestration, and (2) mal-union, in association with bone loss, causing dysfunction and deformity

When the jaw fragments bear teeth, they are readily held in correct occlusal position in the manner illustrated in Fig 256 This defines the gap in the bone, which is bridged by the procedure illustrated in Fig 266 Radiographs of a case treated in this way are reproduced in Fig 267

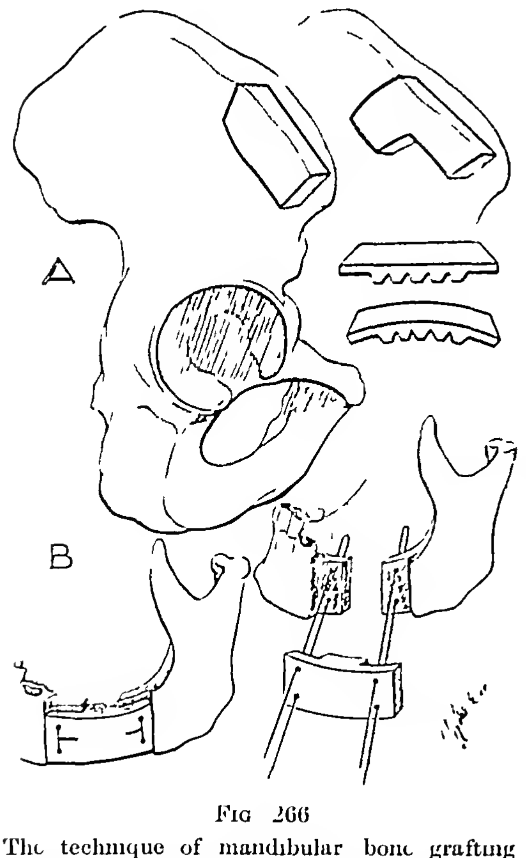


FIG 266

The technique of mandibular bone grafting Straight, curved and angled grafts are illustrated above *Below*, freshening of fragments and method of fixing the shaped graft by wire mattress suture

Success in bone grafting in this region depends on efficient freshening of jaw extremities, attainable only by removal of ample areas of their outer surfaces and exposure of cancellous bone, and firm fixation of the graft, best achieved by mattress sutures of fine-gauge wire These requirements met, it is possible to succeed when no means of stabilizing the fragments are available, as in some edentulous cases Splint fixation should always be used, however, when practicable, for it not only prevents movement at the junctions of graft and jaw fragments but provides the only certain means of ensuring a good occlusal result, the main object of the treatment

If in clearing the fragments the mouth cavity is opened, and this is particularly liable to occur when mal-union must be corrected, no graft should be inserted, for infection and extrusion will almost certainly occur The tear in the mucoperiosteum should be sutured and the skin wound closed with drainage Abscess formation is uncommon, and three to four weeks later treatment may be resumed with safety There is little doubt that many early failures were due to overlooked penetration of the mouth cavity

Reference has already been made to the uncontrolled short posterior cavities In these regions restoration must be made by dental prosthesis and the earlier this is achieved the less will disfiguring contraction occur

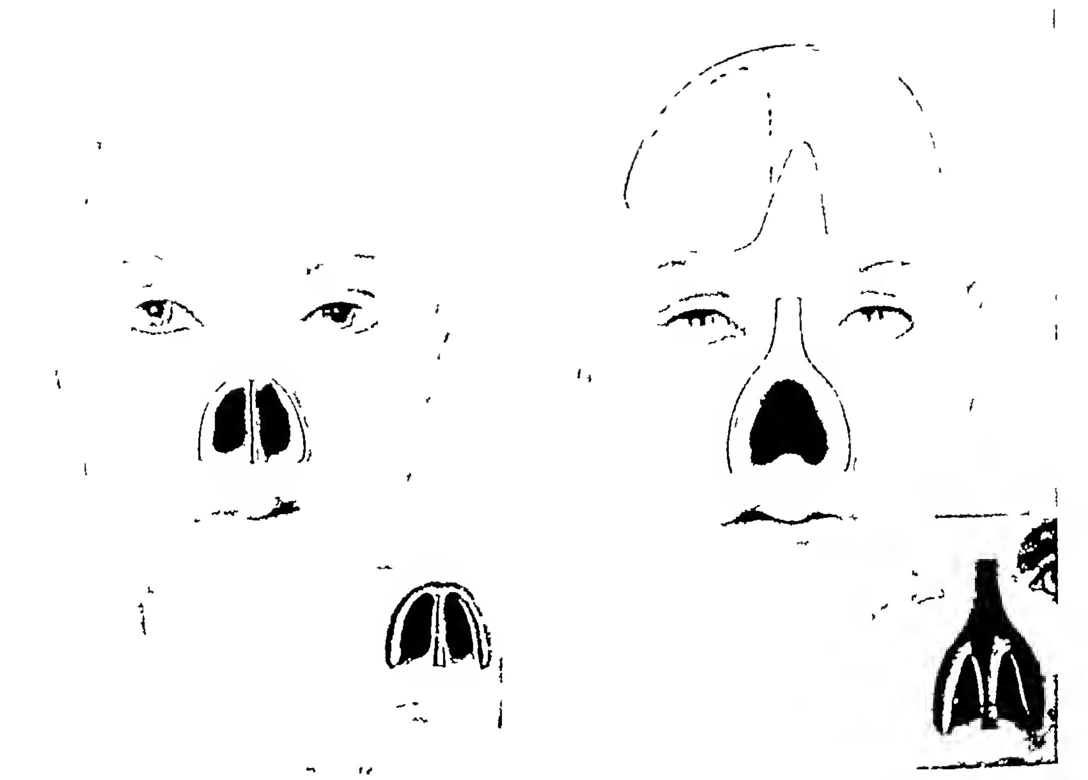
Upper maxillary region—Restoration of contour in this region has already been considered when disfigurement due to uncorrected fractures was discussed

FIG 269

The manner of folding the forehead flap and attaching it to the "stump." The raw surface on the forehead is covered by free skin graft at the first operation and the pedicle of the flap is returned to the forehead after an interval of fourteen days. The mattress suture across the tip of the nose is sometimes employed to prevent hæmatoma formation in this region. It is usually not drawn taut until the day after operation.

NOSE RECONSTRUCTION

Restoration of lining and covering in the nose region is clearly illustrated by Figs 268 to 273 which explain better than words the alternative methods available There is no traumatic loss of nose which cannot be made good in



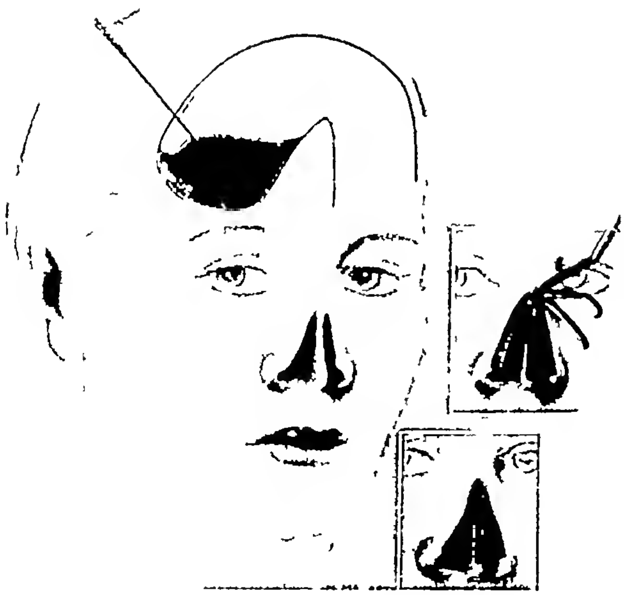


FIG 268

Nose reconstruction These three drawings demonstrate the way in which various degrees of loss of the nose can be treated to produce a more or less standard type of ' stump " to which a forehead flap may be attached The shape and orientation of the forehead flap is also indicated

In the majority of mandibular fractures for which bone grafting has been necessary the buccal sulcus is obliterated, and before a comfortable and stable denture can be fitted the sulcus must be reconstructed by the buccal inlay procedure

Lower maxillary region—Replacement in kind is not practicable for losses in those parts of the maxilla which are related to the mouth or nose cavities In these regions restoration must be made by dental prosthesis and the earlier this is achieved the less will disfiguring contraction occur

Upper maxillary region—Restoration of contour in this region has already been considered when disfigurement due to uncorrected fractures was discussed

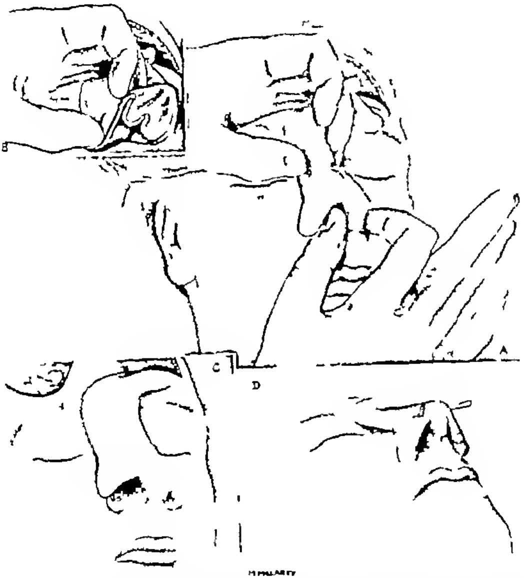


FIG. 269

The manner of folding the forehead flap and attaching it to the "stump." The raw surface on the forehead is covered by free skin graft at the first operation and the pedicle of the flap is returned to the forehead after an interval of fourteen days. The mattress suture across the tip of the nose is sometimes employed to prevent hæmatoma formation in this region It is usually not drawn taut until the day after operation.

NOSE RECONSTRUCTION

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FIG 270

Airman's burn of face Ectropion of right lower eyelid has been treated by Thiersch graft and eversion of lips by similar means Nose has been reconstructed by forehead flap

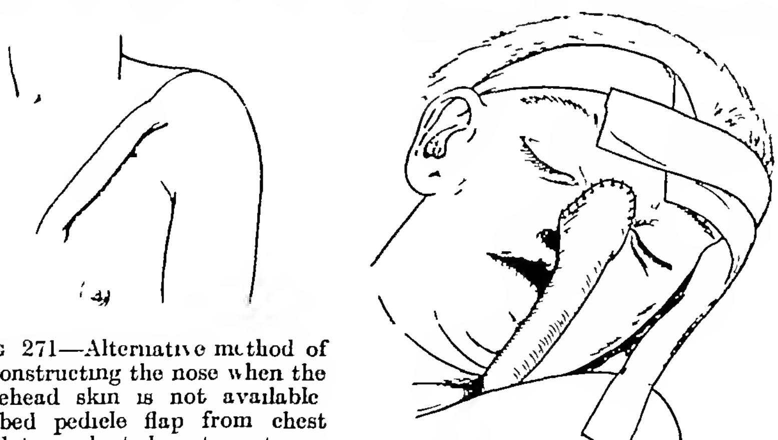

FIG 271—Alternative method of reconstructing the nose when the forehead skin is not available Tubed pedicle flap from chest wall transplanted in two stages, at the second of which the opened-out dependent portion of the flap is infolded to form the nostrils as in Fig 269

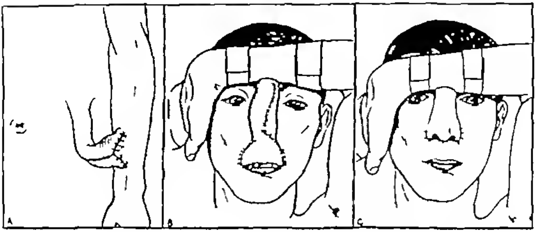

FIG 272

Drawing illustrating the manner in which an abdominal tubed pedicle flap may be transferred via the wrist for reconstruction of the upper lip (B) and afterwards for reconstruction of the nose (C)

FIG. 273

A case of extensive destruction of nose and upper lip treated by the method illustrated in Fig 272.

the patient's own "flesh and blood," but the perfection of the finished feature will naturally depend on the operator's experience and the patience which he and his patient exhibit towards finishing touches. Definition and support for the bridge line and tip may be supplied either by cartilage or bone (see Fig 247)

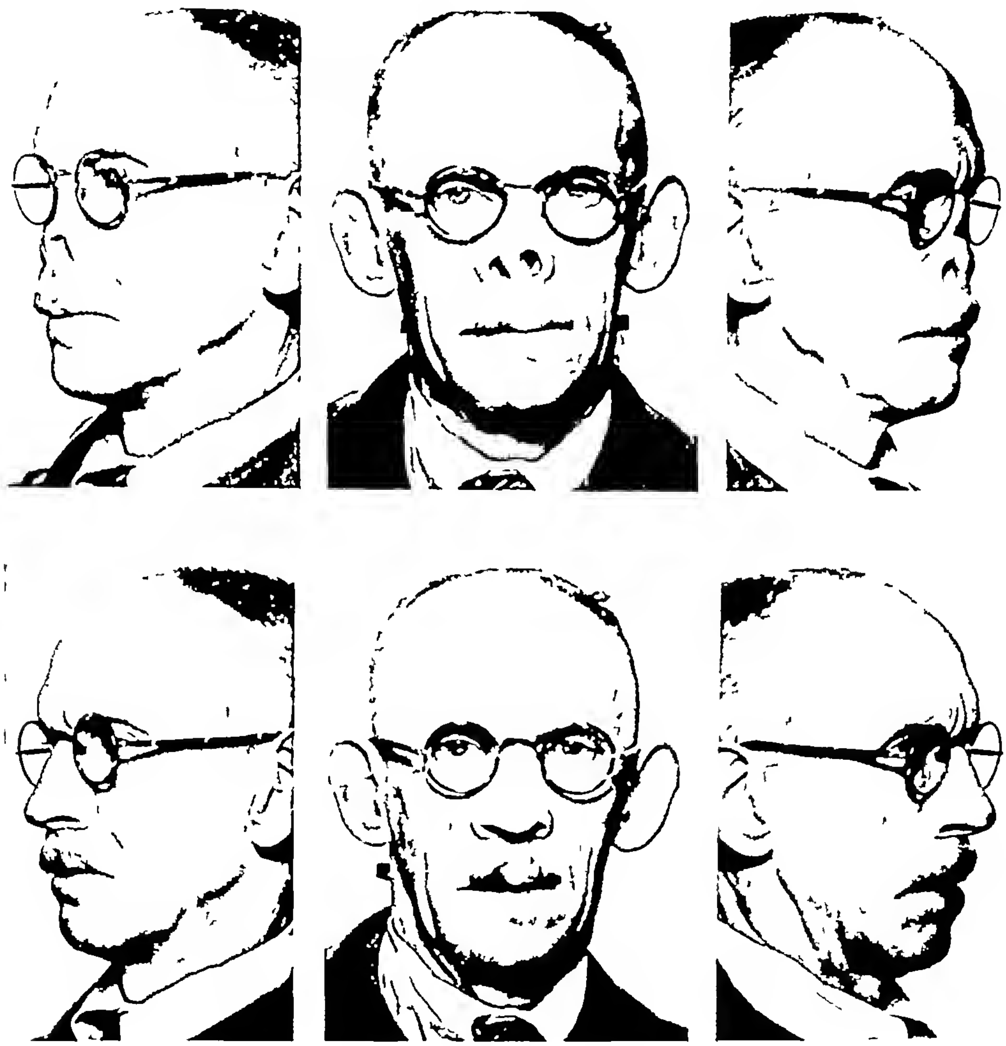

Fig 274

Old G S W face with considerable destruction of nose No reconstruction was carried out after the injury and the patient now prefers to wear a painted metal prosthesis Prosthesis made by Mr Harry Brook

When reconstruction is declined or when there are factors which make it inadvisable (more common in conditions of disease than trauma) recourse must be had to prosthetic measures Fig 274 illustrates a very satisfactory painted metal prosthesis made by Mr Harry Brook, while mention should be made of the excellent work being done by Messrs Clement Clarke Ltd in plastic material

RECONSTRUCTION IN EYE AND EAR REGIONS

Eyebrows may be reconstructed by free full thickness strips of hairy skin from the post-mastoid region

Various procedures for reconstruction of eyelids are described in Chapter LXXII

When the eye has been destroyed and the eyelids have been extensively lacerated the wisest procedure to adopt is excision of all socket mucosa The remaining eyelid skin assisted when necessary by free skin graft provides a clean skin-covered surface free from discharge and readily covered by frosted glass in a spectacle frame an artificial piece of painted metal or an eye shade This is infinitely preferable to and much less disfiguring than, an ill fitting artificial eye supported by thick immobile restored eyelids

Ears may be reconstructed by local flaps assisted by free skin grafts or tubed pedicle flaps supported later by cartilage A further use will be found no doubt for the maternal cartilage-graft procedure developed by Gillies for congenital defects of the pinna It should be remembered however that of all prosthetic appliances, the artificial ear is the most satisfactory

REMOVAL OF FOREIGN BODIES

A whole chapter might well be devoted to this subject for foreign bodies in the face region have a habit of getting into most inaccessible situations Mention will be made of only two of these

Foreign bodies in the antrum are best approached and extracted through an opening made in the anterior wall from the upper gingival sulcus Given good illumination and efficient suction the foreign body is readily seen grasped and extracted through a small opening which produces no external deformity

A foreign body in the zygomatic fossa is best approached from an incision just below the mandibular margin anterior to the angle of the jaw This incision goes straight down to bone and the internal pterygoid muscle is readily stripped from the inner surface of the ascending ramus the rugine carefully avoiding the inferior dental foramen where it might damage the nerve Palpation with the finger will usually locate the foreign body but a long bladed Killian nasal speculum may be employed in conjunction with a headlight if as is preferable the foreign body is to be seen before any attempt is made to extract it

Space does not allow of any discussion of damage to the facial nerve or of injuries to the parotid gland or its duct

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CHAPTER XXXI

WOUNDS OF THE NECK

MOST wounds of the neck fall sharply into two categories —

(*a*) The great vessels are opened, and the patient succumbs in a matter of minutes

(*b*) We marvel at the patient's miraculous escape

When I was serving as a temporary surgeon in the Royal Navy, an able seaman casually consulted me regarding a wound which he had sustained in a brawl forty-eight hours previously he had been stabbed in the neck with a penknife The wound was insignificant, but the cervical sympathetic cord, one of the most inaccessible structures in the neck, had been severed

FIG 275
Compression of the carotid artery over Chassaignac's tubercle
(A, Pomum Adami, B, Cricoid, C, Manubrium)

First-aid treatment—It is possible, indeed it is even probable, that if efficient first-aid treatment could be applied a larger proportion of cases belonging to category (*a*) might reach a surgical service What is the best first-aid measure in catastrophic hæmorrhage from a wound in the neck? The answer which is generally given is to compress with the thumb the common carotid artery, 1½ in above the sterno-clavicular joint, pressure being applied inwards and backwards against Chassaignac's tubercle (Fig 275) How many surgeons, let alone first-aid workers, have ever put the measure into practice? I have had the opportunity only once I was walking through the ward when a patient with malignant ulceration of the neck burst a carotid artery Doubtless the indurated tissues militated against the successful application of the measure, but I found that the thumb applied to the place from which the blood was gushing was far more efficacious

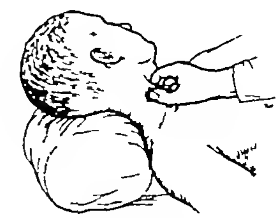

FIG 276
Faraboeuf's method of compressing the common carotid artery

Faraboeuf's method, whereby the common carotid artery is pinched between the finger and thumb, in the manner shown in Fig 276 seems to me to be a better first-aid measure than the one so universally taught

In any case, digital pressure is only a makeshift for a few moments

If the patient's life is to be spared something more radical must be done and the choice lies between two procedures —

(a) *The formation of an artificial hæmatoma*—The skin wound is closed with hæmostats or skin sutures (Fig 277) This will be followed by a massive hæmatoma but in many instances it will enable the patient to be conveyed to a place where reasonable surgical facilities are to hand By performing this service we imitate those cases which war experience has shown reach the field ambulance—cases where a comparatively small external wound becomes plugged with blood clot

FIG. 277
The control of hæmorrhage by closure of the skin and the production of a hæmatoma

(b) *Sir Frederick Treves method*—I feel that if the medical officer on the spot is courageous and possessed of a pocket-case of instruments many lives might be saved by profiting from the teaching of a great practical surgeon Sir Frederick Treves wrote Pressure upon the carotid artery cannot be applied with success or maintained for a serviceable length of time The vessel can however be readily occluded for a while and the carotid circulation arrested without the artery being permanently closed This is effected by exposing the artery in the usual way and passing round it a thick piece of soft catgut This is tied in a very loose loop By pulling upon the loop the circulation through the vessel is at once arrested but is however at once restored when the tension upon the loop is relaxed Sir Frederick quoted four cases in which he used this first-aid measure for hæmorrhage from various parts of the carotid tree He found that by arresting hæmorrhage in this manner bleeding points became occluded by clot and no further treatment was necessary In the case of war wounds this happy sequel is unlikely to occur but at all times during transit with the loop in place hæmorrhage is under perfect control instantly

Wounds with a hæmatoma—It is obvious that the artificial hæmatoma produced by the first-aid measure described above will need exploration at the earliest possible moment It would appear that the same course should be adopted for all cervical hæmatomata The repeated movements of deglutition render the neck an extraordinarily unfavourable site for the consolidation of the clot (Sencert)

The dangers of waiting and watching are manifold They include —

1 A real danger of reactionary or secondary hæmorrhage
2 Embolism, particularly cerebral embolism
3 Spreading infection originating in connection with retained foreign bodies

Should the patient escape these dangers to operate in a few days time is to encounter organizing blood clot and a matting infiltration of anatomical structures which makes the recognition of even major blood vessels a matter of supreme difficulty I feel strongly that the advice to explore every cervical hæmatoma as soon as the patient's general condition permits and the facilities are at hand is sound advice

"Bullet splash" wounds—This type of wound is caused not by the missile itself but by steel splash which results when the missile hits steel armour. These pieces of steel are small missiles of very high velocity and of quite considerable penetration. They are particularly common in the case of fighter pilots, who receive the "bullet splash" wounds from the protective steel plate behind the pilot's seat. In this case they are particularly likely to cause small wounds in the neck, as is shown in the following illustrative case —

Pilot Officer R. W., aged twenty-three years, was admitted to hospital with injuries received while on fighter patrol. He heard bullets fired from in front strike the protective steel plate behind him and immediately felt a pain in the right side of his neck and there was a sudden gush of blood. This continued for several seconds and he began to feel so faint he thought he would have to bale out. Bleeding became less, however, and he was able to make an emergency landing.

On examination he was found to have lost a considerable amount of blood, and there were multiple superficial "bullet splash" wounds of right shoulder and the right side of neck, the latter were oozing blood. A radiograph showed multiple small foreign bodies in the region of the wounds. At operation after preliminary shock treatment, the wounds of the neck were found to be lined with a fine metallic dust. The lowermost wound entered the sternomastoid at about its middle and traversed it to the jugular vein. There was a small hole about 4 mm. diameter in the internal jugular vein with a clot plugging it. This perforation was closed by lateral ligature and all the wounds were excised and sutured without drainage. Convalescence was uneventful.

OPERATIVE TECHNIQUE IN WOUNDS OF THE GREAT VESSELS OF THE NECK

Anæsthesia—The following method will be found satisfactory; it is founded upon experience in cases of Ludwig's angina. The tranquillity of

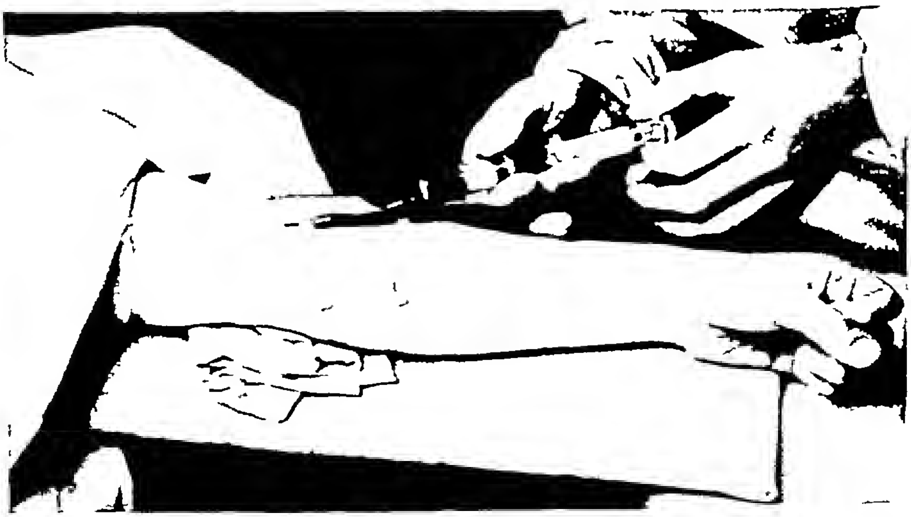

FIG. 278

Administering intravenous anæsthesia via an Edwards' vein-seeker

induction and the absence of anæsthetic paraphernalia near the area of operation are tremendous assets. The arm opposite the side of the neck to be operated upon rests upon a side table. An Edwards' vein-seeker, inserted into a vein at the fold of the elbow, is secured in position by strapping. Evipan or pentothal is injected into the venous system via the vein-seeker (Fig. 278) and a minimal dose need only be given in the first instance: with the vein-seeker in place at any time, more of the anæsthetic can be injected An additional advantage is that as blood plasma or saline will assuredly be needed this also can be injected via the vein-seeker The

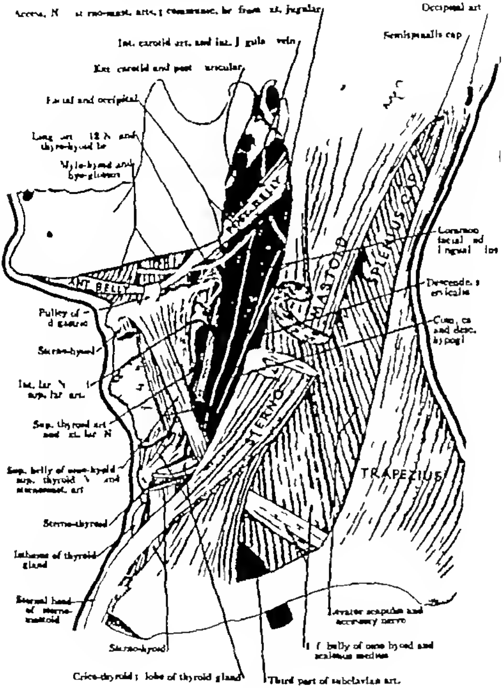

FIG 370
Showing the relationships of the great vessels of the neck. (*Jamieson Regional Anatomy*)

anæsthetist being comparatively free can supervise all the intravenous injections—a further advantageous consideration

Operation.—The keynote of successful surgery in these cases is adequate exposure. Full exposure should be provided in every case.

The patient was shot in the neck; the bullet could be felt in the upper third of the neck at the anterior border of the sternomastoid. There were no signs of arterial injury. An incision was made over the missile, which was extracted. This was followed by tempestuous hæmorrhage. The wound was enlarged and an opening was found in the external carotid artery, which the nose of the bullet had occluded. Artery ligatured. Recovery. (F. C. Pybus.)

The best general incision for exposing the whole of the neurovascular bundle (Fig. 279) is a long oblique incision. The sternomastoid is divided completely. It should be noted that the sternomastoid is a thick-bellied bipartite muscle, and it may be thought that it has been bisected, when only its sternal moiety has been severed. Directly the muscle has been divided considerable access to the interior of the neck is afforded. The assistant should have been instructed previously to pay particular attention to, and be ready to pinch between finger and thumb, the common carotid artery and the jugular vein in the upper aspect of the wound, while by agreement the surgeon will do likewise in the lower part of the wound (or vice versa, in the case of the left side of the neck). Adopting this plan, each will then have his right hand free, the assistant's for necessary swabbing and the surgeon's for accurate application of hæmostats. Naturally at this stage, hæmorrhage, probably terrific hæmorrhage, is to be expected and must be prepared for by an agreed plan. What is to be avoided is the haphazard, blind application of hæmostats, which so often prove damaging and disastrous. If further exposure is required, the wound (Fig. 280) can be enlarged still more by a vertical extension in an upward or downward direction.

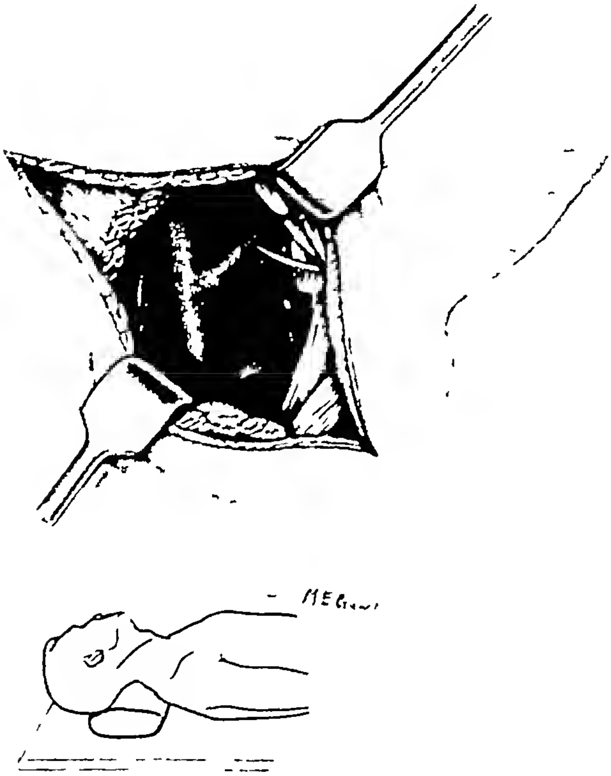

FIG. 280

Standard exposure of the carotid artery near its bifurcation through an oblique incision. If more room is required an extension is made following the anterior border of the sternomastoid in an upward or downward direction.

When the puncture is situated in any part of the carotid artery or jugular vein, between the clavicle and the tip of the mastoid process, it can be seen in a dry field if the above principles are adopted.

Wounds of the jugular vein—The jugular vein when wounded causes most embarrassing hæmorrhage especially when the patient's venous pressure is raised by general anæsthesia All wounds of the jugular vein should be dealt with in the same manner The vein is ligated a reasonable distance above and below and the damaged section resected I have ligatured the internal jugular vein so many times and at all periods of life from tender years to old age that I am perfectly certain that the procedure is not followed by any untoward effect

Wounds of the carotid arteries—The external carotid and of course any of its branches can be ligated with impunity It is improbable that ligation of the internal carotid need be a cause for concern In all these instances the artery should be ligated above and below and the damaged segment resected

When it comes to the common carotid artery a hesitancy to apply these straightforward measures bespeaks of knowledge It is true that if the patient is young and not enfeebled by shock and hæmorrhage the chances of a successful issue are as judged by reported cases not remote but we must take into consideration that naturally it is successful cases which tend to be recorded Experience of civil surgery shows that patients past the meridian of life stand ligation of the common carotid badly and in not a few instances the measure is followed by hemiplegia or a fatal issue Here therefore is an occasion to practise when possible lateral arterial suture or to try a temporary cannula (p 230) in conjunction with heparin (p 237) I see no objection to leaving the wound widely open and gradually over a period of hours or even days tightening the ligature on the common carotid artery During the interval the patient can receive necessary blood and heparin and via the cannula his anæmic brain might be spared a sudden overwhelming shock

Another important point to decide is whether the jugular vein should be ligated in addition to the carotid artery That it should be seems to be substantiated by the following table culled from the Official History of the War —

	Ligature of Artery Alone.	Ligature of Artery and Vein.	Cerebral Complications.
Series I	18	9	8
Series II.	13	11	3
TOTAL	31	20	11

It should be realized that quite a large proportion of patients with wounds of the great vessels of the neck who have been spared to reach surgical aid have died not from the effects of hæmorrhage nor of shock consequent upon surgical intervention but from embolism located at necropsy in the circle of Willis It behoves us therefore when possible to excise a reasonably large segment of the damaged artery which doubtless is the primary seat of the clotting

Especially difficult cases—Looking back on the numerous occasions on which bleeding from some part of the great vessels of the neck has given me anxiety, my present attitude is one of less alarm than formerly. By adopting an orderly technique, in which hæmostats are only applied to actual bleeding points, the situation is soon under control, providing the exposure is adequate. Anywhere between the tip of the mastoid process and the upper part of the clavicle there is no difficulty in getting adequate exposure.

As we proceed farther downwards or upwards difficulties increase, and the call for iron self-control rises proportionally. In a case of hæmorrhage from a large radicle of the bulb of the jugular vein near the base of the

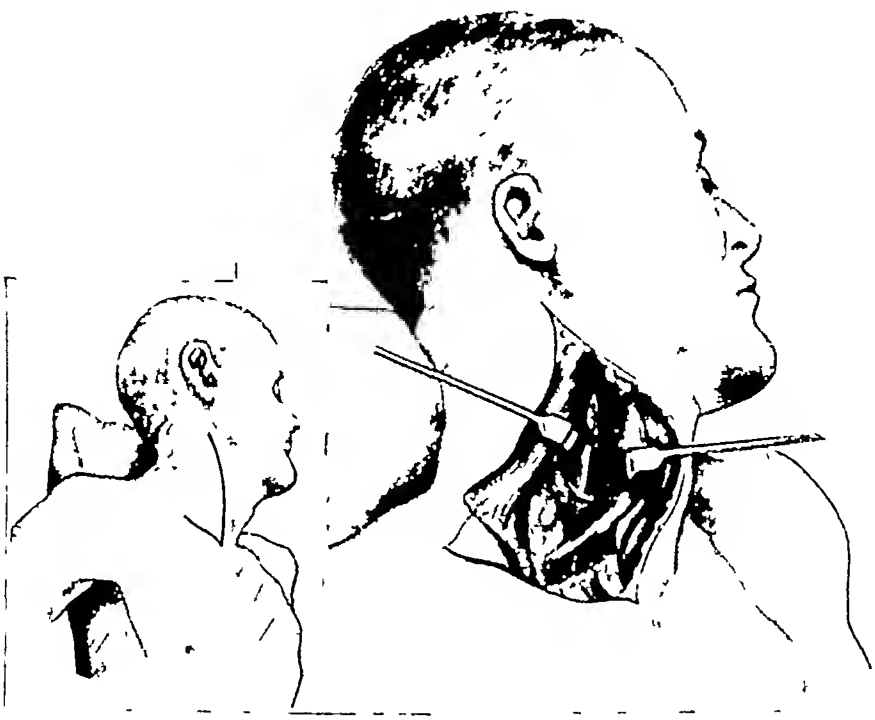

FIG 281

Exposure of the common carotid artery (*After Fiolle and Delmas*)

skull, I was fearful lest a ligature applied might cut through this friable structure. The hæmostat was therefore left in place and the wound sutured loosely about the handles. Twenty-four hours later its ratchet was loosened, and an hour afterwards it was removed quite uneventfully.

As we proceed farther downwards, *i e*, beneath the clavicle, the fear of encountering uncontrollable hæmorrhage reaches its zenith. If the vascular wound is suspected to be low in the neck, Fiolle and Delmas' exposure of the common carotid artery (Fig 281) is a good one, but this, I know to my sorrow, is inadequate for wounds at the extreme end of the jugular vein or carotid artery, *i e* at their junction with the subclavians. Through this exposure hæmorrhage can be controlled by digital pressure, but the insuperable bar to accurate hæmostasis is the clavicle. I would exhort the reader to study and master Sencert's method of exposing the first part of the subclavian vessels which is illustrated on p 213 It is by this method and this method only that a wound at the extreme base of either the jugular vein or the common carotid artery can be dealt with efficiently

CONCURRENT INJURY TO NERVES

The two nerve trunks obviously liable to injury are the vagus and sympathetic It is remarkable that severance of one vagus seems to be followed by surprisingly few symptoms the most constant being the laryngeal phenomena so well known after severance of its recurrent branch

Gordon Bell operated upon an Australian soldier aged twenty for an extensive gunshot wound of the neck The common carotid and the external and internal carotid arteries were ligated and the damaged segment excised The left vagus was found to be divided and the nerve ends were approximated with catgut The patient made an excellent recovery but he could only speak in low whispers However when examined a year later speech was perfect Laryngoscopical examination showed that the left vocal cord moved only slightly

Injuries to hypoglossal and spinal accessory nerves are liable to occur In a major catastrophe such as one with which we have been dealing the loss of function consequent upon the destruction of either or both these nerves is of but trifling significance Of greater importance is severance of cords of the brachial plexus While the surgeon should not concern himself with nerve lesions if the patient s life is swinging in the balance the occasion may arise when an opportunity to perform primary suture is presented it should be taken for secondary suture of the cords of the brachial plexus is difficult and the chances of successful primary suture in the neck where sepsis is controlled easily are great

TREATMENT OF LACERATED WOUNDS OF THE NECK

By applying to the civil surgery of the neck the principles involved in the closed treatment of war wounds I think I may have made an observation which can be given back to war surgery

In the course of my duties connected with the tuberculosis service of the Kent County Council a large number of cases of tuberculous cervical glands are referred to me

For many years in cases of collar stud abscess I have practised the following By an oblique incision following the creases of the neck the abscess cavity is opened and its walls excised The small opening in the deep fascia is found enlarged and the underlying glands dissected cleanly The whole cavity with every vestige of necrotic material is dissected out After strict attention to hæmostasis the skin is closed completely

Latterly the cavity has been insufflated with sulphanilamide powder before closure of the wound

A sorbo sponge is incorporated in the dressing in order that even pressure may be applied and thus minimize hæmatoma formation A first intention scar is obtained in about 90 per cent of cases

When the stage of collar-stud abscess has progressed so far that the skin has become involved and/or sinuses have developed, it is a difficult problem to know best how to deal with the case The very fact that such a case is referred to the surgeon from a tuberculosis service implies that thorough conservative treatment has failed When the skin is involved the procedure outlined above is not successful in a high percentage of instances the wound often breaks down with concomitant complications and unsightly scars

About three years ago, in a case of particularly extensive skin involvement, I excised the unhealthy inflamed skin and proceeded to remove the diseased

FIG 282

The wound becomes filled with granulation tissue under the principles which govern the "closed" treatment of wounds

FIG 283

The same case showing the linear scar which resulted

glands At the end of the operation the great vessels of the neck and a portion of the sternomastoid were quite bare In time past I had undercut healthy skin in an endeavour to close the wound, in this instance such a procedure was impracticable I therefore packed the wound lightly, using gauze moistened with cod-liver oil, and applied a viscopaste bandage in such a way as to immobilize the neck Instructions were given that the dressing should not be interfered with for a fortnight When the dressing was removed it was a great surprise to see that the entire cavity, which before displayed the great vessels of the neck, was lined and partially filled with granulations After a further two weeks the cavity had become filled in completely, and it was covered with skin grafts Only a few of the grafts survived, but the wound continued to heal rapidly, and an excellent result ensued

Since that time I have become bolder in excising involved skin, and have treated some fifty cases in a similar manner. Fig. 282 shows a typical example. There was a skin deficiency 4 in. by $2\frac{1}{2}$ in. with the great vessels displayed at the bottom of the wound. The colour photograph was taken on removing the second Viscopaste bandage three and a half weeks later. What astounds me more than anything else is that in a few weeks this large granulating area, with or without skin grafting, contracts down to a linear scar. Fig. 283 is an unretouched photograph of the same boy two and a half months later. A few Thiersch grafts were placed on the upper part of the wound in this instance, but in only one has grafting been used and the results in the whole series are comparable.

For the past two years I have varied the original technique somewhat. Instead of the cod-liver oil packing, the cavity has been treated with sulphanilamide powder and Allantoin, followed by a vaseline gauze pack. The dressing is left undisturbed for a week or ten days, when it is again insufflated and packed. Pure Allantoin powder is used in the later stages.

I cannot explain how a linear scar results from a large rounded or triangular wound. So much scepticism has been expressed on my testimony that I would not dare to record the observation if it could not be fully substantiated by the careful follow-up of the County Tuberculosis Officer and by photographic proof such as accompanies this chapter.

My argument is this. If the tissues of the neck of a tuberculous subject respond in the remarkable manner described to the "closed" treatment of wounds, the application of the same principle to war wounds of the neck will prove neither dangerous nor disappointing.

Protection for the neck.—Wounds of the neck appear to be common and are certainly very fatal. Towards the end of the 1914-18 war experiments were carried out to show that necklets of Japanese silk were proof against shrapnel splinters possessing a velocity of 600 ft. secs. The 2nd Army reported that they served as protection against small splinters of shrapnel, and recommended five hundred of them per division.

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When the stage of collar-stud abscess has progressed so far that the skin has become involved and/or sinuses have developed, it is a difficult problem to know best how to deal with the case The very fact that such a case is referred to the surgeon from a tuberculosis service implies that thorough conservative treatment has failed When the skin is involved, the procedure outlined above is not successful in a high percentage of instances the wound often breaks down with concomitant complications and unsightly scars.

About three years ago, in a case of particularly extensive skin involvement I excised the unhealthy inflamed skin and proceeded to remove the diseased

FIG 282

The wound becomes filled with granulation tissue under the principles which govern the "closed" treatment of wounds

FIG 283

The same case showing the linear scar which resulted

glands At the end of the operation the great vessels of the neck and a portion of the sternomastoid were quite bare In time past I had undercut healthy skin in an endeavour to close the wound, in this instance such a procedure was impracticable I therefore packed the wound lightly, using gauze moistened with cod-liver oil, and applied a viscopaste bandage in such a way as to immobilize the neck Instructions were given that the dressing should not be interfered with for a fortnight When the dressing was removed it was a great surprise to see that the entire cavity, which before displayed the great vessels of the neck, was lined and partially filled with granulations After a further two weeks the cavity had become filled in completely, and it was covered with skin grafts Only a few of the grafts survived, but the wound continued to heal rapidly, and an excellent result ensued

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SECTION VII

WOUNDS AND INJURIES OF THE SPINE

CHAPTER XXXII

WAR INJURIES OF THE SPINE AND CORD

IN the main injuries of civil life differ materially from those of war Injury to the spinal cord in civil life is nearly always associated with fracture-dislocation of the vertebræ produced by hyperflexion of the spine and while such lesions may be met with in war time *e.g* from the collapse of earthworks and falling masonry falls from a height in standing or sitting posture motor cycle accidents etc the majority of war injuries of the spine are caused by rifle bullets shrapnel balls and bomb or shell fragments a very small minority in modern warfare result from stab-wounds from bayonets swords or sabres By such means the cord may be—

(i) injured directly by missiles
(ii) injured by displaced fragments of bone or dislocated intervertebral disc or
(iii) subjected to concussional or commotional effects

PATHOLOGY

The spinal column—Gunshot wounds usually involve much destruction of bone and muscle masses (Fig 285)

At the site of injury which is most commonly in the dorso-lumbar region is found a bloody effusion derived from vertebral and perispinal vessels the spongy bone of the fractured vertebral bodies continues rarely to ooze for several days Hæmorrhage however seldom gives rise to compression of the cord (Fig 284) At the site of injury may be found not only the penetrating missile and fragments of the splintered bone but also pieces of clothing and dirt carried in by the missile

Thorburn has described the junction of the denser bone of the pedicle with the cancellous bone of the body as a seat of election at which fracture frequently occurs in gunshot injury Wounds of entry and exit may both be present the missile having completely traversed the spine or the missile may be retained either in the bone or adjacent soft parts or lie in the spinal canal Recoil is common after movement of pieces of fractured vertebræ so that rarely is the

FIG 284
Contusion of the cord. No injury to the theca.
(*British Journal of Surgery*)

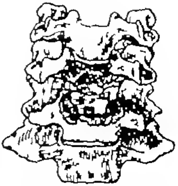

FIG 288

Necrosis of the bodies of the 5th and 6th cervical vertebræ following a gunshot wound. (*Brit sh Journal of Surgery*)

permanent destruction of some fibres there is considerable temporary damage to others causing an interference with conduction which may be ascribed to œdema hæmorrhage and the effects of concussion Infection may render these effects permanent by leading to sclerosis of the cord and fibrosis of its envelopes

It is often insufficiently stressed that injuries to the spinal roots — hæmorrhages lacerations rupture—constantly accompany cord injuries

2 CONTUSION AND COMPRESSION—The spinal cord lesions are extremely variable and bear no direct relationship to the meningeal injury Severe damage to the substance of the cord may coexist with intact meninges The bruising or contusion causes the cord to swell, mainly from œdema and a form of colliquative necrosis small punctate hæmorrhages may be present but a gross circumscribed intraspinal hæmorrhage (hæmatomyelia) is rarely seen The investing pia mater tends to prevent expansion of the cord and favours an up-and-down spread of œdema

In this connection it is of interest to note that A. R. Allen showed experimentally that the symptoms produced by severe contusion can be relieved by incising the dorsal column at the level of the injury thus allowing the swollen fibres to expand and their subsequent recovery to occur It is stated that this operation should be performed within a few hours of the injury The risks of severe damage to the cord from this procedure in any but the most expert hands, however are so great that it cannot be recommended

Recovery of a swollen contused cord may be further retarded or prevented by compression from encroachment on the spinal canal by indriven fragments of bone or other foreign bodies

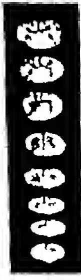

FIG 289

Sections taken at various levels showing widespread hæmorrhage in a case of spinal concussion. (*Brit sh Journal of Surgery*)

In cases of laceration contusion and compression of the cord the presence of a wound penetrating the dura constitutes an immediate danger from meningitis but pia arachnoidal adhesions may in some cases limit this to the vicinity of the wound

3 SPINAL CONCUSSION—The spinal column and with it the cord may be concussed as the result of an explosion a fall, or the jarring effect of the passage of a rifle bullet or bomb fragment in the neighbourhood of the spine Consequently there may be a transient interruption of function giving rise to extensive and profound paralysis sensory loss etc This passes off rapidly and may leave little evidence of damage It is therefore wise in the absence of evidence of direct injury to the cord to suspend judgment on the nature of the cord damage for a few days In any case it is difficult to distinguish between concussion and the milder degrees of contusion of the cord, and the precise pathogenesis of cord concussion is still obscure

In all forms of any considerable violence to the cord a certain amount of hæmorrhage takes place and minute hæmorrhages may be present throughout a large section apparent extent of the bony injury (Figs 286, 287) any measure of the damage inflicted upon the contents of the vertebral canal

The cord—Injuries of the cord from wounds may be classified as due to —

1 Laceration by direct injury
2 Contusion and compression
3 Concussion

1 Laceration by direct injury—The resistant and elastic dura mater almost invariably shows less damage than the enclosed cord A fissure or ragged

Fig 285

Dorsal portion of spine, showing extensive fracturing of neural arches and spinous processes (*British Journal of Surgery*)

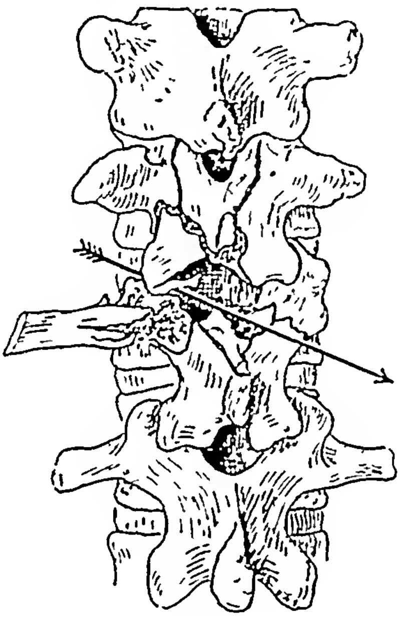

Fig 286

Extensive fracture of the vertebral arches of 11th and 12th dorsal vertebræ The arrow indicates direction taken by the missile

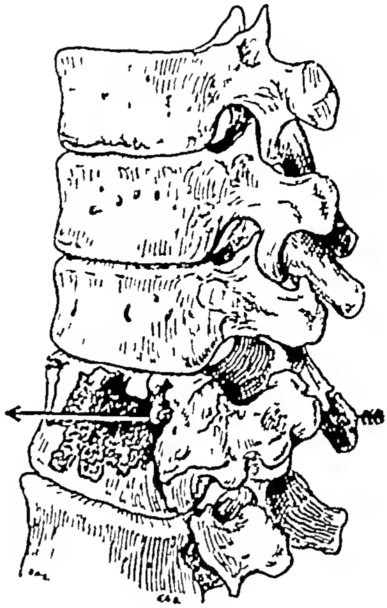

Fig 287

Trans spinal injury with perforation of the body of 12th dorsal vertebra The arrow indicates direction taken by missile (*British Journal of Surgery*)

slit may be found, the edges of which tend to rejoin Occasionally one finds an extensive tear, but it is quite exceptional for the dura mater to be torn open even when the cord is completely crushed or severed The missile or indriven splinters of bone may completely transect the cord, but a clean-cut section is not seen The ends may be crushed, lacerated or scattered, the edges of the wounded cord are jagged, friable and pulped, and on separation show hæmorrhagic foci

The injury in such cases is partially or completely irreparable, as a smaller or greater number of the conducting fibres are severed Contrary to what occurs in fish and amphibians, there is in mammals no satisfactory evidence of regeneration of the divided cord either in the fœtus or the adult (Hooker) In every case of partial laceration of the cord, in addition to permanent destruction of some fibres there is considerable temporary damage to others causing an interference with conduction which may be ascribed to œdema hæmorrhage and the effects of concussion Infection may render these effects permanent by leading to sclerosis of the cord and fibrosis of its envelopes

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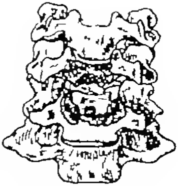

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Necrosis of the bodies of the 5th and 6th cervical vertebræ following a gunshot wound. (*British Journal of Surgery*)

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Sections taken at various levels showing widespread hæmorrhage in a case of spinal concussion. (*British Journal of Surgery*)

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In all forms of any considerable violence to the cord a certain amount of hæmorrhage takes place and minute hæmorrhages may be present throughout a large section of the cord (Fig 289) It was probably owing to the comparative youth of most of the patients with cord injuries seen in the 1914-18 war that a large hæmatomyelia spreading in the grey matter was found very rarely Hæmorrhages which are generally small and insignificant are not uncommon in the soft meninges, and large subdural hæmorrhages (hæmatorachis) occasionally occur, but extramedullary hæmorrhage sufficient to cause compression of the cord is almost unknown

Spinal shock—Spinal shock is the phase of suppression of function in that part of the cord suddenly isolated from the rest of the central nervous system For a variable time after sustaining such a lesion the distal part of the cord is incapable of subserving even the simplest reflex

High transection in the frog leaves all four limbs flaccid and inactive to stimuli for half an hour or so, and the higher the animal in the scale the more pronounced and persistent are the symptoms of spinal shock In human adults a similar picture has been described

That spinal shock is due to a sudden interruption of impulses which pass down the cord is suggested by the observations of Gordon Holmes He has demonstrated that in a unilateral lesion of the cord evidence of spinal shock may be confined to the injured side

CLINICAL PICTURE

At the moment of injury the victim feels as if his "body has been cut in two" or as if he has had "a kick in the back" Consciousness is retained, but he falls helplessly to the ground unable to move except in the case of injury to the lower lumbar cord, when he may be able to drag himself to a place of safety by using his arms and upper trunk muscles

Complete lesions of the cord—If the cord has been completely severed he shows—

(i) COMPLETE FLACCID PARALYSIS BELOW THE LEVEL OF THE LESION

(ii) REFLEX CHANGES —

(a) Below the level of the lesion the *deep reflexes are absent*, above they are present and may be brisker than normal

(b) The abdominal reflexes are absent below the lesion as a rule, though the cremasteric and bulbocavernosus reflexes are often retained

(c) The plantar response may be flexor or extensor, and too much significance should not be attached to either finding The former is the more common, though the extensor toe response does not exclude complete section Even the flexor response differs from that normally obtained in being slower and having a longer latent period than normal It should be emphasized that the plantar response is best obtained by *stroking* the sole, especially along the outer border strong pressure on the sole will mechanically cause a flexor response to be simulated

(iii) LOSS OF ALL FORMS OF SENSATION BELOW THE LEVEL OF THE LESION —At the level of the lesion there may remain an ill-defined zone in which touch is retained but which shows pain and thermal loss This is due to intramedullary damage above the level of complete section interfering with crossing central intraspinal fibres (compare the dissociated anæsthesia of syringomyelia) More rarely loss of joint and vibration sensation due to posterior column damage is found above the level of complete sensory loss Pain may occur with fractures or injuries involving the nerve roots above the severed cord but it is not a marked feature as a rule

(iv) SPHINCTER DISTURBANCES—Retention of urine with distension of the bladder and overflow incontinence occurs in practically all cases As a rule constipation follows the injury unless the fæces are softened by aperients or a bowel infection when incontinence results

These four groups of clinical signs are constant and of themselves sufficient evidence of complete ablation of function in the cord below the level of the lesion. They result from (i) direct injury at the site of the lesion and (ii) spinal shock below

Other symptoms and signs will, however be observed. Below the lesion the skin is dry though above it sweating may be marked Both the pilomotor and dartos reflexes are maintained Acute bedsores often develop but must be regarded as avoidable complications in the large majority of cases. Erythematous patches at pressure points may precede the appearance of bedsores and œdema of the paralysed limbs is not uncommon Priapism a classical symptom is rarely present

It must not be forgotten that at the site of the injury to the cord nerve structures may be damaged which will often help to localize the level of the lesion *e.g* if the eighth cervical and first dorsal segments are the seat of a destructive lesion Horner's syndrome and wasting of the intrinsic muscles of the hand will be present In general, however the level of sensory loss will localize the site of injury (Fig 290)

In many cases of complete section of the cord complications appear and kill the patient before any change in the nerve signs occurs If however toxic complications can be avoided the isolated distal cord gradually recovers from its spinal shock and begins to show evidence of *reflex activity* (spinal automatism) This second stage commences seven to twenty-one days after the injury and is first evidenced by the reflex which results from stimulation of the sole of the foot This gives rise at first to adduction and flexion of the toes accompanied later by contraction of the inner ham strings, and still later the toes show an extensor response Gradually the fully developed flexion reflex is seen—flexion of hip adduction of thigh flexion at knee dorsiflexion of ankle and extension of toes, the opposing muscles being inhibited and relaxed This reflex can be produced by a noxious stimulus applied to any part of the lower extremities still later stimulation of one lower limb will give rise to a strong reflex response on the stimulated side and a weaker response on the opposite side until finally evidence of the *mass reflex* is obtained. Its components are —

(i) A flexor spasm of the lower limbs and abdominal wall

(ii) Partial evacuation of the bladder even when its contents are relatively small

(iii) Sweating below the level of the lesion

(iv) Occasional penile erection and seminal emission

Although at this stage a noxious stimulus applied to any site below the lesion will result in a "mass-reflex," the most receptive field is the genital area

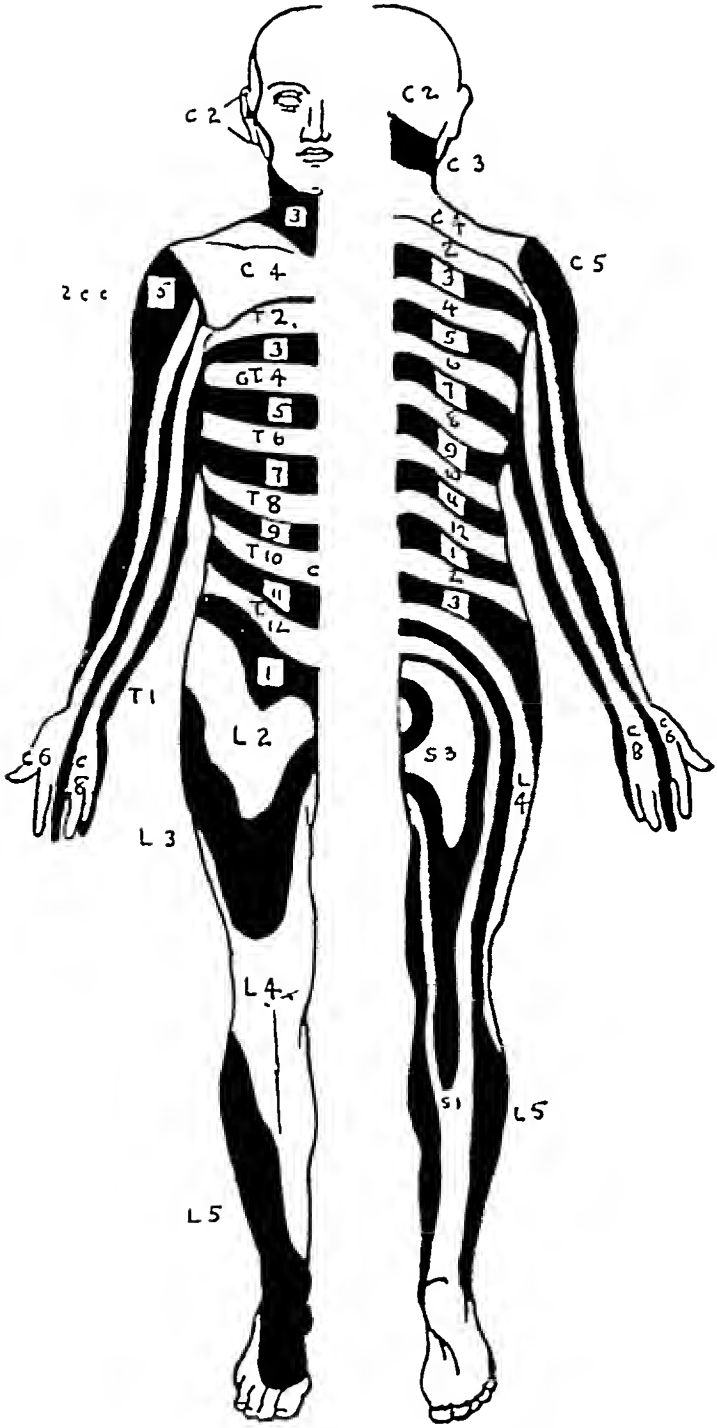

Fig 290
Sensory segmental localization in the spinal cord

On the twenty-first to fifty-third day, knee and ankle jerks may be evoked which gradually become brisker, though a sustained clonus is never seen Inducing a "flexion-reflex" will inhibit both knee and ankle jerks At this stage automatic emptying of the bladder and rectum may occur At first this automatic evacuation is observed on catheterization, later automatic micturition appears Now also the vasomotor balance becomes more stable, and œdema on lowering the legs is less marked The skin looks healthier and of good colour, bedsores tend to heal

After a period, sometimes of months but often of years, and almost always as a consequence of toxic or febrile complications, this reflex automatism of the cord below the injury fails, and the reflexes above described gradually *disappear in reverse order to their appearance after the injury, until the initial flaccidity returns*

Incomplete lesions of the cord—The majority of spinal cord wounds show *incomplete anatomical* section of the cord A bridge of cord tissue usually remains as evidence of partial anatomical continuity But this bridge is rarely normal It is indeed often so changed that physiological isolation of the lower segment is almost as complete as in total anatomical section of the cord with however this difference While complete section of the cord is an irreparable lesion incomplete section permits though admittedly rarely of possible restoration of function Thus the diagnosis of complete from incomplete section of the cord is no mere academic pastime it is a guide both to treatment and prognosis

Rarely owing to spinal shock and concussion can a decision be made for a few days (Fig 291) then however symptoms and signs appear which point to incomplete section of the cord These are —

(i) CONSERVATION OR PARTIAL RETURN OF SENSATION BELOW THE LEVEL OF THE LESION—All forms of sensation—touch pain heat cold vibration and joint sense must be tested and the sensitivity of both anal and urethral mucosa observed Special attention should be paid to the perineal penile and scrotal areas where retained sensation is often overlooked The frequency with which deep pressure pain *e.g* squeezing and pinching the toes is retained when other forms of sensation are lost is worth noting The return of sensation is sometimes accompanied by the appearance of pains—vague in site and character sometimes spontaneous in others induced by movement and massage and very resistant to analgesics—in the anaesthetic areas (anaesthesia dolorosa) These pains must be distinguished from the root-pains which may accompany complete section of the cord *e g* complicating fracture-dislocation of the spine and occurring at the upper limits of the anaesthetic region

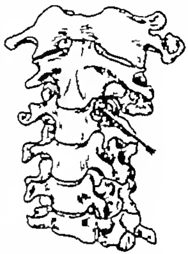

FIG 291

Fracture of transverse and articular processes on left side of 3rd cervical vertebra. The neural arch remained intact (*Brit Journal of Surgery*)

(ii) RETURN OF MOTOR POWER—After the first few days or weeks slight voluntary movements may reappear *e.g* in the toes These must be distinguished carefully from those involuntary movements resulting from reflex automatism in complete section of the cord

(iii) REFLEX CHANGES—An *incomplete* lesion is suggested when the deep reflexes accompanied by an extensor toe response and an early flexion reflex return within a few days of the injury

Riddoch has called attention to other reflex changes in incomplete section He points out that movements of the *flexor* type are the only primary motor reactions observed in complete transection of the cord In incomplete section the movements may simulate movements of progression or be entirely *extensor* in type Moreover if flexor movements occur they have not the uncontrolled character of those occurring in complete section of the cord The posture of the lower limbs in complete section is slight flexion at hip and knee slight adduction of thigh and dorsiflexion of foot and toes in partial lesions the limb lies extended at hip and knee with foot and toes pointing slightly in The "flexion-reflex" in partial section of the cord which results from a noxious stimulus applied to the sole differs from the "mass-reflex" of complete section in that —

1 The flexor movement is less violent.
2 Invariably there is a crossed extension reflex
3 Active extension of the stimulated limb associated with flexion of the contralateral limb follows the initial flexion phase
4 The abdominal wall is involved only with stimuli of intense nociceptive character
5 The receptive field of the flexion reflex does not extend higher than the knee The sole remains the area of lowest threshold value for eliciting the reflex

When the spinal cord has been completely divided the reflex in the ipsilateral limb is invariably *uniphasic* and flexor, the extension which follows is due to relaxation of the flexors and gravity

Two reflexes obtained in partial section only are —

(*a*) Homolateral or bilateral extension of the lower extremities excited by moving the prepuce forward over the erected glans penis, or by noxious stimulation of the upper parts of the thighs or of the perineum

(*b*) Active extension of the lower extremities when the distal portion of the sole of the foot is pressed upwards, the limb having first been passively flexed This is analogous to the extensor thrust of Sherrington's decerebrate and spinal animals, and may often start stepping movements in the two lower limbs

Two other points should be noted In complete section of the cord (Fig 292) the knee jerk even when it reappears is a simple twitch, in partial section there is a slow and deliberate relaxation due to retention of postural tone Only in a complete section of the cord is facilitation of bladder emptying possible

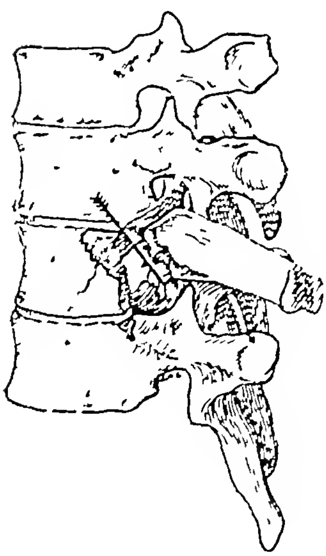

FIG 292
Oblique trans spinal injury of 4th dorsal vertebra The spinal cord was severed by the missile (*British Journal of Surgery*)

It will thus be seen that complete section of the cord resembles the "paraplegia in flexion" of Babinski, partial section more closely simulates "paraplegia in extension"

(iv) TROPHIC CHANGES afford no certain diagnostic criteria, but the absence of bedsores and œdema of the paralyzed part, or their rapid regression after appearing, favours a partial lesion

The two commonest partial lesions of the cord seen in war injuries are (i) the Brown-Séquard syndrome, and (ii) a transverse posterior hemisection involving the posterior columns, pyramidal tracts and dorsal cerebellar tracts on both sides

CLINICAL DIAGNOSIS OF SPINAL CORD INJURIES

In all suspected cases of cord injury four questions are to be answered —

1 Is there structural damage to the cord?
2 What is its nature?
3 Is there complete or partial section of the cord?
4 What is the level and extent of the cord injury?

1 **Is structural damage present?**—The typical pictures of cord lesions have been described Not all paralyses following wounds of the spine are however due to cord or cauda equina injury Such wounds may be followed by *hysterical paralysis* often accompanied by anaesthesia This will be recognized by —

(*a*) THE PRESERVATION OF BOTH DEEP AND SUPERFICIAL REFLEXES the plantar reflexes instead of showing a normal response might be absent but an extensor response (Babinski) is unequivocal evidence of organic disease

(*b*) MUSCLE TONUS REMAINS—The elevated leg suddenly unsupported does not fall limp and jelly like to the bed Indeed if the patient s attention is distracted the leg will often maintain its posture after the supporting hand has been withdrawn

(*c*) SENSORY LOSS DOES NOT CORRESPOND TO ANATOMICAL SEGMENTS—It is usually stocking or sock in type and can be modified by suggestion

(*d*) SPHINCTER ACTION IS UNIMPAIRED overflow incontinence is never seen

(*e*) APPROPRIATE PSYCHOTHERAPY will improve the paralysis in minutes or hours

Cases have been seen in which both hysterical and organic paralysis have coexisted Careful neurological examination will usually help one to assess the part played by each It should be noted also that severe fractures of the spine and pelvis may give a false paraplegia —an immobility of the lower limbs from the pain of movement either active or passive

Not all organic paraplegias result from *cord* lesions Bilateral cerebral injuries, especially gutter wounds in the superior longitudinal sinus region may give rise to paraplegia or quadriplegia Hemiplegias due to cord injuries practically always show some evidence of the Brown-Séquard syndrome

2 **The nature of the lesion**—To determine the nature of the lesion the clinical features may be supplemented by (*a*) X ray and (*b*) cerebrospinal fluid examination

Radiographs should be taken in both anteroposterior and lateral positions (Figs 203 and 204) Fractures and rarely displaced fragments of bone may be revealed though Sargent reported in the last war what we have confirmed in this that bony fragments driven into the spinal canal can rarely be found by X ray The missile might be seen its site is mainly of value in indicating its probable path through the tissues Its resting place is no indication of the damage for which it is responsible

Cerebrospinal fluid examination will show red blood cells in practically all cases when the cord is damaged whether by laceration or contusion It will show evidence also of a complicating infection in the subarachnoid space provided the infected area is not closed off by adhesions but even

Fig 293 Fig 294

Anteroposterior and lateral views of a revolver bullet in the spinal canal of a young seaman operated upon in October 1940—inset shows bullet removed

here a polymorphonuclear cell increase is usually found in the fluid The main value of cerebrospinal fluid examination, however, is to determine whether or not there is compression of the cord Lumbar puncture should be performed and the presence or absence of obstruction to the subarachnoid space ascertained by manometry Compression over the jugular bulbs at the root of the neck, with the patient lying in the left lateral position and a lumbar puncture needle connected to a manometer (Fig 295) introduced into the lumbar pond, normally causes a sudden rapid rise from 100 or 150 mm of water to 300 mm or more, and on release of the compression results in an equally rapid fall This constitutes the Queckenstedt phenomenon (Fig 296) and fails to occur if the subarachnoid space is obliterated, or occurs in a modified form if it is partly obstructed In subarachnoid block which has been present for any length of time, chemical examination of the cerebrospinal fluid from the lumbar pond shows evidence of stagnation, viz , it approximates to the blood plasma in chemical composition, *e g* , the protein is increased above its normal of 20 to 30 mg per cent it often has a yellowish (xanthochromic) appearance and there is no cellular increase These signs

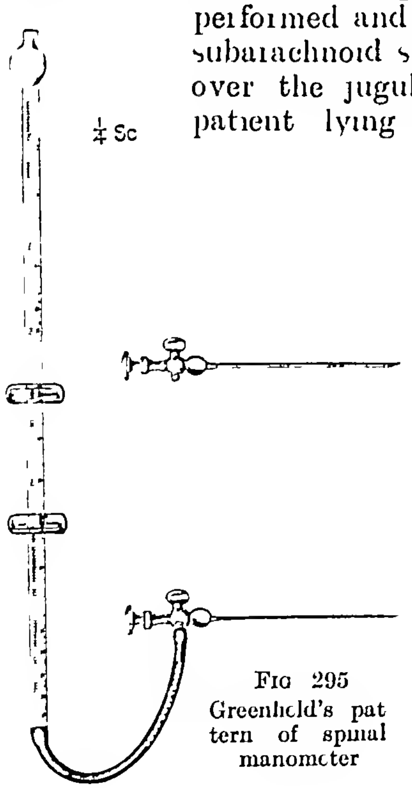

Fig 295 Greenfield's pattern of spinal manometer

point to compression of the cord, not to the nature of the compressing agent, which might be the missile, a bone fragment, scar tissue and lesions with fluid loculi (meningitis serosa circumscripta), abscess, or very rarely blood clot. Injection of air or lipiodol for contrast myelography is rarely indicated or helpful in injuries of the cord.

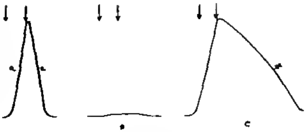

Fig. 206.
Queckenstedt's phenomenon.
A. Normal reaction. B. Complete spinal block. C. In complete spinal block—a rapid rise has occurred, but owing to partial obstruction the curve shows a prolonged fall. The arrows indicate the onset and release of jugular compression.

3. **Is the section complete or incomplete?** This question has been fully discussed above. The sense in which the words complete and incomplete are used should be recalled. No single sign points to complete anatomical section of the cord. The evidence will point to complete or incomplete interruption of the cord as a functioning structure. It is not for several days after the injury even in only minor anatomical section that signs may begin to appear bearing witness to the continuity of the spinal axis.

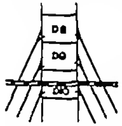

Fig. 207.
The actual injury is through the 10th dorsal segment, but the apparent level from sensory loss will be the 8th dorsal segment because of injury to the 8th and 9th dorsal nerve roots.

4. **The site of the lesion and its extent.**—The entry and exit wounds or the resting place of the missile in the body are no certain indication of the site of the lesion or its extent, for the path of the missile is seldom straight. Sensory loss will usually localize approximately the site of the lesion (see Fig. 200), but the length of cord damaged is often difficult to ascertain for three reasons:—

(*a*) Whether the cord is intact or damaged below the upper level of a complete lesion, the signs are the same.

(*b*) Wounds damage spinal roots as well as the cord, hence the site of the lesion of the cord is often lower than the signs would indicate (Fig. 207).

(*c*) Above the site of direct injury there is often a conical upward prolongation (Fig. 208) of hæmorrhage or myelomalacia in the central part of the cord, giving a zone of dissociated anæsthesia (loss of sensation to pain, heat and cold, but retained touch, joint and vibration sense) above the level of complete sensory loss.

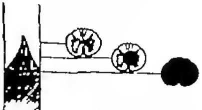

Fig. 208.
Note the conical projection upwards from the site of the injury, damaging central fibres and thus giving "dissociated anæsthesia" above the level of complete sensory loss.

COMPLICATIONS

"Il faut se garder de cette sorte de fatalisme néfaste qui consisterait à dire que lorsque la moelle est touché par le traumatisme le malade est perdu. Bien au contraire, de très notables améliorations sont possible, à condition d'éviter des complications graves." Thus wrote Pierre Marie and Roussy in 1915.

Experience has served to confirm the fact that death results most often not from

FIG 293

FIG 294

Anteroposterior and lateral views of a revolver bullet in the spinal canal of a young seaman operated upon in October 1940—inset shows bullet removed

here a polymorphonuclear cell increase is usually found in the fluid The main value of cerebrospinal fluid examination however, is to determine whether or not there is compression of the cord Lumbar puncture should be performed and the presence or absence of obstruction to the subarachnoid space ascertained by manometry Compression over the jugular bulbs at the root of the neck, with the patient lying in the left lateral position and a lumbar puncture needle connected to a manometer (Fig 295) introduced into the lumbar pond, normally causes a sudden rapid rise from 100 or 150 mm of water to 300 mm or more, and on release of the compression results in an equally rapid fall This constitutes the Queckenstedt phenomenon (Fig 296) and fails to occur if the subarachnoid space is obliterated, or occurs in a modified form if it is partly obstructed In subarachnoid block which has been present for any length of time chemical examination of the cerebrospinal fluid from the lumbar pond shows evidence of stagnation, viz , it approximates to the blood plasma in chemical composition, *e g* , the protein is increased above its normal of 20 to 30 mg per cent , it often has a yellowish (xanthochromic) appearance and there is no cellular increase These signs

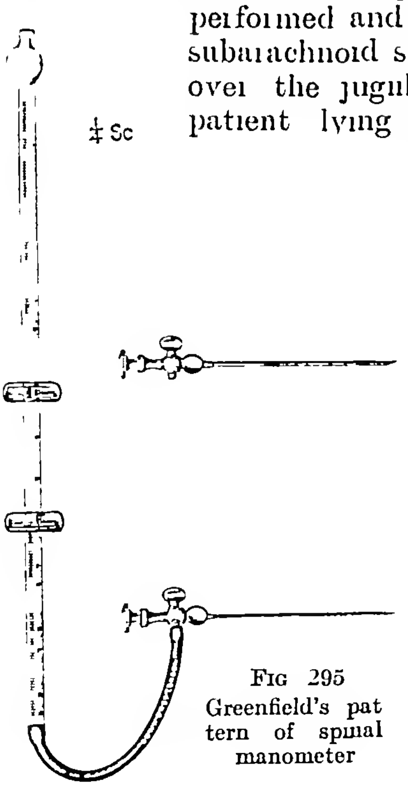

FIG 295
Greenfield's pattern of spinal manometer

the chest or abdomen and pointing out that the damage to the spinal cord is done when the wound is inflicted he comments that owing to the nature of the lesions the treatment of these spinal injuries is naturally unpromising This was true in the last war and much the same may be said to-day but nevertheless there is much that may be done for some of these patients and in certain cases treatment is by no means as unpromising as it may at first sight appear Its problems are (1) *medical* including the prevention of complications in addition to maintaining the general strength and counter acting the effects of shock and (2) *surgical* especially the indications for surgical intervention and operative methods

(i) **Prophylaxis**—As a prophylactic in the early *stages* of *all gunshot* injuries of the spine sulphanilamide tablets (1 gm) should be given four hourly for forty-eight hours and the *dose gradually reduced* *As a first* aid measure particularly in those cases for whom early operation is not possible the use of *finely powdered sulphanilamide* or *sulphathiazole* which is claimed to be less toxic applied directly to the wound is to be recommended. As *much as a dessertspoonful may be safely used*

(ii) **Care of the skin**—As soon as possible the patient should be placed *between smooth sheets on an air or warm water* bed rucks in the bed clothes should be avoided A cradle will prevent the bed-clothes from directly touching the paralysed lower limbs but it should be sufficiently high to prevent chafing of the knees if involuntary flexor spasms occur Hot-water bottles should be well protected and never placed in direct contact with the anæsthetic skin A daily bath with soap and water should be given and afterwards the skin thoroughly dried and then hardened by gently massaging with eau-de-Cologne or surgical spirit special attention being paid to points of pressure If the skin is inflamed alcohol may prove too irritating and a boric acid lotion (a saturated solution of boric acid in cold water about 15 gr to the ounce) should be substituted After this friction is completed and when the skin is quite dry a dusting powder should be applied *e g* bismuth subgallate or a mixture of boric acid (1 part) zinc oxide (2 parts) and starch (3 parts)

Pressure points must be specially protected by small pads rings or bandages, so that the pressure is spread and taken by surrounding parts though care must be taken to avoid direct and prolonged pressure by the protecting ring The heel should lie in the hollow of a soft ring the feet should be supported by a bolster if marked adduction of the thighs is *present the knees* and heels should be separated by a pillow or ring To prevent prolonged pressure on one site and hypostasis of the lungs, the patient's *position should be altered every few hours* but care must be taken to avoid chafing the skin by lifting and not dragging, him A rope or chain overhanging the bed allows *the patient to lift himself* but from this the danger of dragging and chafing of buttocks and lower limbs is considerable

If bedsores of the blister type develop *the serous content should* be aspirated and the skin left intact as a protective covering if ulceration supervenes compresses of boric lotion or of hydrogen peroxide (10 volumes) should be applied for ten to fifteen minutes twice daily and the part then dressed with unguentum hydrargyri ammoniatum or a paste made of equal parts of zinc oxide talc adeps lanæ and paraffinum mollis album the cord injury but from its complications Of these the commonest are —

1 **Meningo-myelitis**—Where the dura is opened by the wound, infection may spread and involve cord and meninges (Fig 299) This may cause (*a*) a diffuse purulent meningitis which is rapidly fatal and hence was rarely seen in this country in the 1914-18 war, (*b*) a local infection shut off from the healthy cord and meninges by adhesions

Fig 299
Fragment of shell impacted in the cord Localized meningitis (*British Journal of Surgery*)

2 **Bedsores**—These are liable to appear at pressure sites—sacrum, heels, toes, buttocks, malleoli, trochanters, back and scapulæ—and show three stages (*a*) a dry red patch appears at a point of pressure which in twenty-four hours becomes bruised, black and necrotic, or a large blister, filled with blood or purulent fluid, forms, (*b*) a discharging ulcer gradually spreading to produce (*c*) gangrene These are neither inevitable nor invariably fatal Whilst trophic disturbances might play a part by impairing tissue resistance, the two factors dominantly responsible are (i) pressure which is constantly applied to the same area because of the patient's analgesia and immobility, and (ii) infection from fæces and urine

3 **Urinary infection** is frequent, and cystitis, ascending pyelonephritis, urethritis, prostatitis epididymo-orchitis, may all be found

4 **Respiratory complications** are more frequent than many observers recognize Areas of congestion and broncho-pneumonia are often present even when cough and expectoration are absent Patients with cord injuries are very susceptible to cold and hypostasis Thus warmth and change of posture are indicated

5 **Rare complications are** —

(*a*) Abdominal distension, vomiting and hiccough, acute dilatation of stomach
(*b*) Hyperpyrexia—usually a harbinger of death
(*c*) Atrophy of the paralysed muscles, which may be masked by massive œdema of the limbs
(*d*) Stiffening of the joints from capsular adhesions

TREATMENT

That great army surgeon, Ambrose Paré, as long ago as 1545 urged surgeons to greater boldness in cases of spinal wounds and advised removal, where possible, of splinters or pieces of bone which had been driven in and were compressing the cord and nerves, while in 1762 Louis performed what was almost a formal resection of the spine upon M de Villedon, Captain in the Regiment of Vaubecourt, who was paralysed from a gunshot wound of the back, received at the battle of Amenebourg Fragments of bone were removed and the patient finally recovered sufficiently to be able to walk. (Donald Armour)

Writing of the spinal injuries seen in the early part of the 1914-18 war Gordon Holmes stated, "A large proportion of cases of spinal injury die soon after the infliction of the wound from shock or associated wounds of

CHAPTER XXXIII

WAR INJURIES OF THE SPINE AND CORD—*continued*

OPERATIVE TREATMENT

THE *question of operation which in spinal injuries usually resolves* itself into some form of laminectomy is a difficult one and must depend upon a conception of what surgical intervention may be expected to accomplish In compound injuries the general principle of the early arrest of hæmorrhage and the prevention of infection applies to the spine as to other regions In closed injuries however early laminectomy is but rarely called for In the majority of cases of fracture-dislocation (as may occur through hyperflexion of the spine produced by a fall of earth or sand bags on the bent shoulders) any damage to the cord is done by a sudden nipping at the time of the accident and provided early and complete reduction of a fracture-dislocation is effected and maintained by an appropriate plaster-of Paris jacket the cord is very unlikely to be compressed subsequently If there is any doubt as to whether or not there is cord compression the condition of the subarachnoid space should be investigated (see p 341) It must be remembered that recovery of a contused cord may be delayed by the presence of a foreign body even though there may be slight If any actual compression of the cord by the missile or bone fragment

Radiology—Good X ray pictures both anteroposterior and lateral views should be obtained as soon as possible The presence of foreign bodies may be shown and some idea though admittedly often a very incomplete one of the degree of damage may be obtained While in some cases gross displacement of vertebræ may indicate complete division of the cord, in others recoil may result in the X ray appearances being inconsistent with the damage which has actually been produced

Gunshot injuries—The objects of operation are (*a*) the arrest of hæmorrhage and prevention of sepsis (*b*) the relief of pressure on the cord and (*c*) the removal of *accessible* foreign bodies.

If seen early let us say within ten hours of the injury and the patient s condition permits first principles namely the arrest of hæmorrhage and surgical cleansing of the wound by excision, should be practised. If the dura is intact it should not be opened. A plaster spinal jacket is then applied, to put the parts at rest If *as sometimes happens with gunshot* injuries much loss of substance has occurred so that it is not possible to effect closure after excision of the wound it should be dusted with sulphathiazole powder and lightly packed with vaselined gauze A plaster jacket is then applied If seen at a later stage when infection may be assumed to be well established, operation is not indicated unless there is a persistent cerebrospinal fluid

Deep sloughs may be removed by curetting. Pus should be evacuated, the gangrenous edges of the ulcer cut away and the surface dusted with powdered sulphanilamide or sulphathiazole.

Hypodermic injections should be given above the level of the lesion, as even so slight a trauma may lead to trophic changes in the anæsthetic areas.

(iii) **Care of the bladder** (see Chapter XXXIV).

(iv) **Care of the bowels**—To avoid soiling the skin, the patient should be constipated with opium for transport. When in hospital a simple aperient—for example, a teaspoonful of liquid extract of cascara or two teaspoonfuls of confection of senna—may be given each night, and next morning a pint of warm normal saline may be given as a rectal washout. Leaking might persist for half to one hour, so that the patient should be left for an hour on a special large-sized india-rubber air-cushioned bed-pan and later an absorbent pad should be applied to the anus. Strong purgation should be avoided.

Abdominal distention from ileus causes much local distress, respiratory difficulty and often hiccough. Relief sometimes follows the passage of a rectal tube, but if in spite of this distension persists, 1 c.c. of pituitrin should be given subcutaneously or intramuscularly and repeated in four to six hours if necessary. Turpentine and other drastic enemata may cause sloughing and should be avoided.

Every care must be taken to sterilize the skin of the back. The whole area should be carefully shaved so as to remove even the smallest hairs washed thoroughly with ether soap and water and gently swabbed with biniodide of mercury and finally spirit (70 per cent) Apart from this but little should be done to interfere with the patient and the administration of strong purgatives before operation is to be strongly deprecated. If the operation is not performed as an emergency the patient will have been in bed for some days beforehand and should have accustomed himself to lying either fully or three-quarters prone as it is in this position that he is nursed after the operation Diet should be full up to the night of operation, and on the morning of operation a cup of beef tea may be given two hours or more before the anaesthetic is begun

LANDMARKS OF SPINE—In most cases of war injury for which operation is to be undertaken the position of the lesion will be obvious from X ray photographs and the site of the wound but it is useful to remember the level of certain bony landmarks in the spine The tip of the spinous processes may readily be identified by palpation the most prominent is that of the first thoracic vertebra but the uppermost to form a visible projection is usually the seventh cervical—the so-called vertebra prominens—except when the neck is acutely flexed when the sixth may be more apparent The root of the spine of the scapula normally lies opposite the third thoracic spinous process while its inferior angle is at the level of the seventh thoracic spine The highest part of the iliac crest constitutes a very constant land mark being level either with the upper edge of the fourth lumbar spine or the space between this and the third lumbar spine

RELATION OF VERTEBRAL SPINES TO BODIES—The tips of the spinous processes of the cervical the first two dorsal and last four lumbar vertebræ pass almost horizontally backwards and are therefore nearly opposite their corresponding bodies The tips of the spines from the third to the twelfth dorsal inclusive are opposite the bodies of the next vertebræ below them, whilst the tip of the first lumbar is about opposite the intervertebral disc beneath

The operation—The patient being sufficiently under the influence of the anæsthetic is gently rolled over on to his face and sandbags are so placed that the operation field is supported and made as convex as possible For the dorsal region little support is required, as this portion of the spine is the most prominent If the lesion is in the lumbar region it is generally necessary to have this portion of the body well supported so that the lumbar concavity is as far as possible obliterated For lesions in the cervical part of the column the head requires supporting in a slightly flexed position on some form of outrigger such as is used for cerebellar operations An operation table should be used fitted with an extension head rest and shoulder supports (these may however be easily made from a series of slabs of sponge rubber) to lift the chest clear of the table so that thoracic respiratory movements are not impaired

The surgeon stands on the left hand side of the patient The actual steps of the operation vary considerably in the hands of individual operators but these variations are as a rule only matters of detail which each has mastered in his own way The first essential is to obtain a good view The fistula which some attempt may be made to arrest, such as by the application of a piece of clean muscle to the dural opening No operation which entails opening the theca is permissible in the presence of a septic wound In a frankly infected case operation may occasionally be called for, to bring the wound, by providing better drainage into as clean a state as possible In wounds of the spine, as in those occurring elsewhere in the body, the sulphanilamide drugs have proved valuable, both given internally and directly applied in powder form Except in the early case of compound injury, when operation is performed with the object of protecting the patient from infection, laminectomy is better avoided both during spinal shock when the functional depression may be sufficient to turn the scale against recovery from what is a severe operation, and also in the presence of gross infection Furthermore, during the phase of spinal shock it is neither possible to estimate the degree of damage to the cord nor to recognize whether the lesion is complete or not, and operations for complete transverse lesions are futile, since once the cord has been completely divided recovery of its distal part does not take place This does not apply to the elements of the cauda equina for which suture may be attempted justifiably Of the war injuries of the cord treated in the last war however, it is interesting to read in the "Official History" It is a little remarkable that not a single example has been met with in which the cauda equina has been sutured"

Once spinal shock has passed off it is important to know whether the cord lesion is complete or not (p 343) If there is evidence that it is not, laminectomy is indicated, if—

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(*b*) progressive recovery is not maintained, *i e*, an arrest of returning conduction takes place,

(*c*) there is persistent and severe root pain,

(*d*) the onset, at a still later period, of a failure of conduction due to meningitis circumscripta serosa This will be suspected or clearly demonstrated by the tests carried out for investigation of the state of the subarachnoid space,

(*e*) the appearance of late root pain such as may be due to radicular arachnoiditis

The operation of laminectomy—PREPARATION OF THE PATIENT—Every care must be taken to avoid the presence of infection—bedsores constitute a source of danger inasmuch as local infection of the wound may take place from them and lead to meningitis, while a general depression of resistance may be the result of absorption from them In this last connection also, cystitis and bronchitis may be troublesome factors to be avoided or lessened in intensity if at all possible

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The operation of laminectomy—Preparation of the patient—Every care must be taken to avoid the presence of infection—bedsores constitute a source of danger inasmuch as local infection of the wound may take place from them and lead to meningitis, while a general depression of resistance may be the result of absorption from them In this last connection also, cystitis and bronchitis may be troublesome factors to be avoided or lessened in intensity if at all possible

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processes a clean smooth surface of bone consisting of the posterior aspects of the laminæ is left in the field (Fig 303)

Of the various ways of effecting an entry into the spinal canal the simplest and safest is to trephine one of the laminæ with a $\frac{3}{4}$ in trephine from which the pin has been removed The lowest lamina is selected for the site of entry as thereby the opening is made away from the site of the lesion and the laminæ above are more readily removed by the surgeon working with his right hand It is always advisable to make the opening away from the site of the lesion since there is a possibility that the posterior surface of the dura may be adherent to the deep surface of the laminæ and thus be injured at the time of entry In certain cases of injury an opening may already be found in the lamina if so it may be easier to enlarge this opening with a pair of small bladed rongeur forceps Some surgeons prefer to remove all the bone with cutting forceps such as those of Horsley or with Trotter's nibbling forceps (Fig 304) instead of using a trephine to make an initial entry Chisels should not be used owing to the concussing

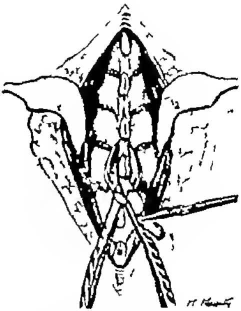

FIG 303

Removal of the spinous processes by means of angled bone-cutting forceps.
Royal Northern "Operative Surgery"

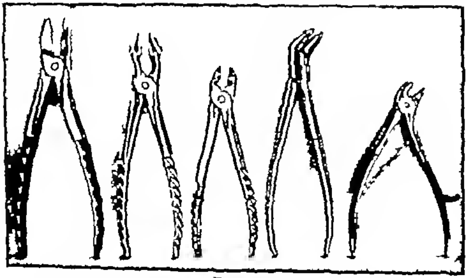

FIG 304

Forceps used for removing spinous processes and laminæ

effect of hammering The bone may be dense and hard and considerable force required to divide it It must be remembered that this force must at all times be directed outwards away from the dural tube and its contents incision should be at least 6 to 8 in. long, and should have its centre opposite the site of the lesion. The skin of the back has a comparatively poor blood supply when compared with that of the neck or scalp. For this reason and because it can be readily extended if necessary, a straight mid-line incision is the most satisfactory and is to be preferred to the "flap" types of exposure. The first incision should pass through the subcutaneous tissue but no deeper, and at this stage a few small subcutaneous vessels require the application of hæmostats. Skin protection cloths should now be attached to the wound edges, and it is advantageous to have these made of thin rubber as a protection to the skin of the back from the frequent hot saline washing of the wound. The incision is now deepened, the superficial aponeurosis is divided and the deeper muscles are laid bare. An incision is next made through the muscle attachments to one side of the spinous processes and immediately against the bone and, keeping very close to the bone, is carried directly down to the laminæ (Fig. 300). This muscle separation is followed by considerable venous oozing which is readily controlled, however, by packing the wound with a roll of hot moist gauze. This is left *in situ* while a similar separation is carried out on the opposite side of the spinous processes. The wound on this side is now packed with gauze, while that from the first incision is removed to allow the separation of the muscles to be completed. A broad osteotome is the best instrument for this purpose (Fig. 301) and is kept close to the bone so as to effect a subperiosteal separation. When the muscles have been completely separated the greater part of the hæmorrhage will be found to have ceased as the result of the gauze compression. Oozing is further controlled by means of self-retaining retractors. Those designed by the author are shown in Fig. 302 and have proved satisfactory.

FIG. 300

Separation of the muscles from the spinous processes

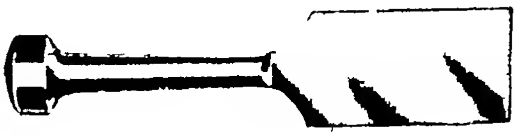

FIG. 301

Author's pattern of broad bladed osteotome for turning the erector spinæ muscle mass out of the vertebral groove subperiosteally

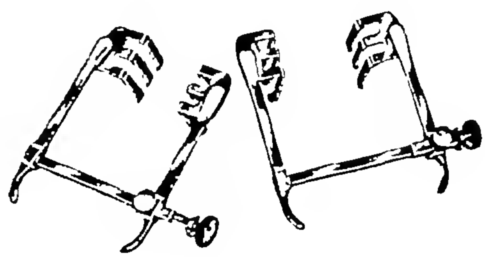

FIG. 302

Author's pattern of laminectomy retractors

The spinous processes are now isolated and an appropriate number are removed with bone-cutting forceps, the interspinous ligaments at the limits of the wound having been divided first with scalpel and scissors. After removal of these showed in his experimental work with the exposed brain of animals lessens operation shock A suction apparatus should be used to remove the surplus blood stained saline and keep the field clear If it is desired to rotate' the cord in order to examine its anterior surface a slip of the dentate ligament is severed from its dural attachment held by fine forceps and gently drawn outwards and backwards If nerve roots are divided it is necessary to remember the accompanying vessels which are easily controlled with silver clips.

CLOSURE—Care should be taken to secure a perfectly bloodless field before beginning the closure If the dura has been opened it is closed with fine silk and the muscle masses are approximated in layers. Fine silk is used throughout except in frankly infected cases, when catgut is employed The divided aponeurosis is sutured and the skin wound closed with fine, interrupted waxed thread sutures passed on straight cutting needles A dry dressing is applied

After-treatment—Dependent upon the patient's condition intravenous saline plasma or a blood transfusion may be required either during the latter part of the operation or on return to the ward but such measures are not usually necessary Acute post-operative dilatation of the stomach should be watched for and should it arise treated by washing out the stomach and changing the position of the patient Failure to recognize this condition may lead to a fatal result It is most likely to occur after high cervical operations and is probably the result of interference with certain descending impulses in the cord Frequent vomiting of small quantities of dark fluid after a laminectomy should at once raise a suspicion of the onset of acute gastric dilatation The patient is best nursed in the prone or semi prone position, and if he has been accustomed to this position for a few days before the operation is undertaken will not find it exacting Unless there has been an inflammatory condition the wound should not be disturbed for at least ten days

Many patients are paralysed at the time of the operation, and it not infrequently happens that even if the paralysis is incomplete before the operation this may be increased for a few days afterwards as a result of operative manipulation however carefully carried out The after treatment is therefore associated with special difficulties in the nursing and wherever possible a nurse should be chosen who has had experience of cases of this type Special attention must be paid to the care of the skin bladder and bowel on the lines already described after operation frequent change of position is especially important if pulmonary complications are to be avoided

A special spinal bed is a great advantage especially if fitted with an outrigger for the head when the patient is lying fully prone and a supporting attachment for the tidal drainage apparatus for the bladder

For the first few days after operation the temperature may rise to 102 or 103 F but it generally falls again rapidly and this rise alone must not be taken as an indication of the onset of sepsis This immediate post operative rise of temperature probably results from the liberation of cerebro-spinal fluid into the perineural tissues and is usually greater if the dura has not been sutured

This must be kept in mind throughout and is particularly important when removing fragments of bone, missiles, etc After an opening is made into the spinal canal the surface of the underlying dura is cleared of the epidural fat, and the laminæ above are carefully separated by means of some form of seeker or dural separator One blade of a pair of cutting or nibbling forceps (Fig 304) is now inserted under the lamina, which is then divided This is repeated on the opposite side and the neural arch removed Great care must be exercised in this procedure (Fig 305) Once the lamina is divided and the spinal canal opened, the groove in the canal is widened, and for this purpose guillotine forceps (Fig 306) are useful These forceps are so made that they cut upwards (i e, outwards) and hence exert no pressure upon the cord The remaining surface of the dura is now carefully cleaned of epidural fat and examined so that the presence of any adhesions, scarring or thickening may be observed The surrounding surface of bone is also examined for evidence of injury

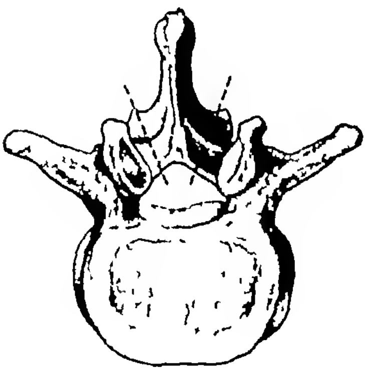

Fig 305
Indicating direction of cut necessary for division of neural arches

Unless there is a definitely septic focus outside the dura, the next step consists in its division. As in the case of the bone, it is always better to commence the incision in a position remote from what is likely to be the situation of the lesion, so that if the cord is adherent it is in less danger of injury As the dura is divided, sutures of fine silk or catgut threaded on a small, curved, round-bodied needle, and held in a needle-holder, are passed through its edges, three or four along either side These act as slings for retracting the edges of the tube after it is opened Every care should be taken to incise the dura only If this be successfully accomplished the arachnoid will bulge through the length of the incision, and any increased tension or any abnormal opacities or thickening, as in meningitis circumscripta serosa, will be apparent Frequently it is possible to inspect the cord and its relations through the unopened, transparent arachnoid The arachnoid is next opened by snicking it with a small sharp knife, cerebrospinal fluid escapes and the membrane is further divided with fine scissors Throughout the operation a stream of hot saline should be used This as Horsley

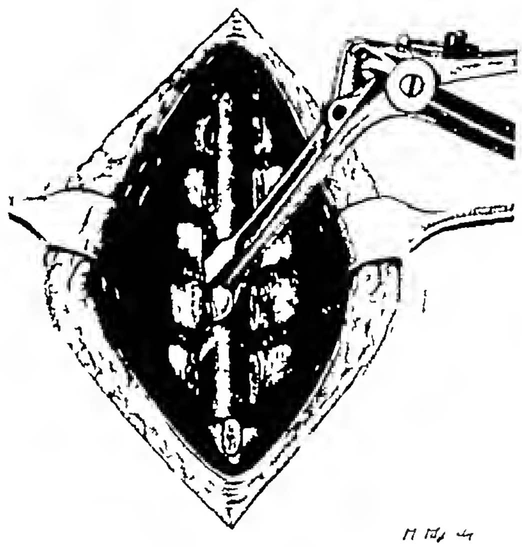

Fig 306
Removal of neural arches with Hudson's guillotine forceps

independence Each case of residual paralysis must be studied as an individual problem and means devised to secure not only the maximum recovery and comfort but also the optimum rehabilitation

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LEAKAGE OF CEREBRO-SPINAL FLUID—Very rarely, difficulties may be caused by the escape of cerebro-spinal fluid, but should not occur if the wound has been carefully closed in layers Should a cerebro-spinal fluid fistula form it usually closes spontaneously within the course of a week or two, during which time the utmost precautions should be taken to guard against infection, and gauze dressings wrung out of spirit (70 per cent) should be used When leakage is present following an operation which has been performed within two or three weeks of the infliction of a perforating wound, there is considerable risk of the onset of sepsis, which may later terminate in meningitis

EXCESSIVE SWEATING AND MUSCULAR SPASMS—These components of the "mass-reflex" may demand special treatment Excessive sweating, by increasing skin moisture, increases the risk of infection Involuntary flexor spasms are not only painful but disturb rest and sleep Thus afferent stimuli, *e g*, allowing the bed-clothes to touch the lower limbs, should be avoided Atropine sulphate ($\frac{1}{100}$ gr) once or twice daily will help to control the sweating

Flexor spasms are often relieved by radiant heat applied for twenty minutes daily, but sedatives are usually necessary, *e g*, luminal ($\frac{1}{2}$ to 1 gr) with hyoscine hydrobromide ($\frac{1}{100}$ gr) morning and night, or

℞

Tinct gelsemii	♏xx
Tinct stramonii	♏x
Sodii bromidi	gr x
Liq arsenicalis	♏iii
Aq chlorof ad	℥i

T d s, p c

If pain is severe, aspirin (10 gr) thrice daily combined if necessary with codeine phosphate ($\frac{1}{4}$ to $\frac{1}{2}$ gr) should be given Stronger opiates are better avoided, but in some cases morphia may be required

PHYSIOTHERAPY—Gentle passive movements of the paralysed limbs should be carried out from the first These improve the circulation, help skin nutrition and prevent articular adhesions in the paralysed limbs Massage of the paralysed limbs should be instituted as soon as spasticity lessens Constant efforts should be made to persuade the patient to move the limbs voluntarily

When cauda equina injury is responsible for the paraplegia the same general principles apply, and there must also be careful splinting of the limbs to avoid overstretching of the affected muscles

GENERAL—In the treatment of spinal injuries meticulous attention to detail is of paramount importance Physical treatment is not the only requisite The patient must be surrounded with an atmosphere of hope and encouragement His mind must be occupied with work, games, and the like so that he has little time to dwell on the more tragic aspects of his disability As soon as possible he should be taken out of doors and given a wheel-chair, an auto-cycle, a paddling frame or other device which confers a sense of independence Each case of residual paralysis must be studied as an individual problem and means devised to secure not only the maximum recovery and comfort but also the optimum rehabilitation

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CHAPTER XXXIV

THE MANAGEMENT OF THE BLADDER IN SPINAL INJURIES

IN war, spinal injuries leading to disorders of the bladder function are commonly due to gunshot wounds, though they may also result from fracture-dislocations of the spine with crushing of the spinal cord

THE BEHAVIOUR OF THE BLADDER IN RELATION TO THE CORD LESION

When the spinal cord is divided completely, and if the patient survives, the immediate effect on the bladder is paralysis and retention of urine In gunshot wounds of the spine the cord is often cut across or is pulverized by the missile, in other instances the same effect is produced by forcible impaction of a piece of bone Less often the missile damages only a part of the spinal cord, but even so the bladder is extremely likely to be paralysed completely Retention of urine also occurs in severe injuries of the cauda equina

The immediate loss of the contractile power of the bladder is attributed to 'spinal shock" This produces retention of urine which is absolute until such time as the bladder has become greatly overfilled, then urine begins to dribble away, a state, in fact, of retention with overflow Such retention of urine is not necessarily permanent for instance, when the spinal cord has been only partly damaged, eventually normal micturition may be re-established Again, when the lesion is complete, an automatic bladder may presently develop, giving rise to periodic reflex micturition, or, as it is also called, *active incontinence* Active incontinence only occurs when the spinal injury and the concomitant descending degeneration is above the third and fourth sacral segments

The transition of retention of urine with overflow to active incontinence is a gradual process To commence with small amounts of urine are passed involuntarily at varying intervals, the bladder still remaining at least partially distended Gradually the amount of residual urine decreases

WHEN THE INJURY INVOLVES THE LUMBAR ENLARGEMENT OR THE CAUDA EQUINA

Of necessity, either the bladder centres in the cord or their pathways must be destroyed It has been stated that in these cases the urine dribbles away from an empty bladder as fast as it runs into it This is incorrect, at first there is always retention with overflow

Concerning the subsequent establishment of micturition in these patients, authorities are not unanimous. Case records show that while a form of involuntary micturition may occur it differs from the active incontinence which develops in cases of higher lesions of the cord. If the power of micturition is recovered when these lower lesions exist, it is usually effected by means of powerful contractions of the abdominal wall which appear to act by raising the intra-abdominal pressure and also by producing a direct stimulus to the bladder musculature

THE PROMPT RELIEF OF RETENTION OF URINE IS OF PARAMOUNT IMPORTANCE

In every case of retention of urine occurring in connection with a spinal injury the need to provide adequate treatment for the bladder is urgent This is true whether or no there is reason to believe that ultimately recovery of function in some form or other will occur It is quite wrong to delay such treatment on the score that the retention is due to spinal shock Even in these cases the bladder requires skilled attention for days or weeks Sir John Thomson Walker found that in thirty consecutive cases the average duration of the period of retention was fifty five days

Another important aspect of these cases is to realize that not only is the contractile power of the bladder abolished but there is also loss of all vesical sensation Unlike other forms of retention of urine the patient does not demand relief on account of pain Again, the trophic nerve supply is interfered with and just as bedsores develop from undue pressure on the integument when the trophic nerve supply to the part is damaged so if prolonged distension is permitted the bladder mucosa becomes the seat of mucosal ulceration

THE SUPERVENTION OF URINARY INFECTION IS DISASTROUS

During the last three months of the 1914-18 war, Vellacott had under his care at Boulogne sixty-six gunshot wounds of the spine for an average period of three weeks They had arrived there twenty four hours to seven days after being wounded Of these sixty six cases, twenty-one died during those early weeks, and the causes of death were as follows —

2 due to high cervical injury and respiratory failure
2 due to ascending meningitis
9 due to complicating injuries
7 due to pyelonephritis
1 due to rupture of the bladder

Fifty out of the sixty-six patients suffered from retention of urine and in spite of the fact that they had been grouped together in order that their bladder states might be given special study and attention seven (14 per cent) died of pyelonephritis during these first three weeks

In 1917 Thomson Walker reported on 339 spinal bladder cases These were seen by him usually within a fortnight of being wounded, and at intervals from then onwards 47 2 per cent of the patients died of urinary sepsis within two months. At a later date he also had much to do with a group of cases cared for at the Star and Garter Hospital Seventeen per cent of these died from urinary sepsis within the next three years Thomson Walker estimated that the total death rate from urinary sepsis was 80 per cent

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It is equally certain that the tied in catheter can be employed with perfect satisfaction in cases of paralysed bladder For instance I know of a case of a total transverse lesion of the spinal cord which was treated at the National Hospital Queen Square with a tied in catheter for no less than ten months The patient recovered though with a chronic urinary infection

The comparatively recent method of tidal drainage (see p 363) is often conducted through a tied in catheter and this method has been extolled particularly in American neurological clinics

The position regarding the tied in catheter can be summarized thus It should be condemned even more whole-heartedly than intermittent catheterization unless the patient is admitted to a well-equipped hospital where the facilities for adequate management of the indwelling catheter can be guaranteed and the tidal-drainage apparatus is available Details of inserting and managing the catheter under these conditions are set out under Tidal Drainage (p 363)

Expression of the bladder—Once again this is a method to be condemned except under very special circumstances It is dangerous on account of the risk of rupturing the bladder Its sole indication (and even so opinion is not unanimous on the matter) is in retention due to lesions of the cauda equina or lower lumbar centres Never under any circumstances should an attempt be made to grip the bladder and squeeze out its contents Expression should take the form of massage and gentle pressure upon the lower abdomen

Aspiration of the bladder is a method which has much to recommend it under urgent conditions It is far less likely to lead to infection than any form of catheterization and therefore is particularly valuable in the field and in similar extenuating circumstances The one stipulation is that written details must accompany the patient giving the time and the amount aspirated with the request that the procedure be repeated six or eight hours later if the patient has not reached the base hospital by that time Aspiration can be repeated time and again without danger for in the great majority of cases the urine is aseptic and no extravasation will occur unless the bladder is allowed to become grossly over-distended The pubes must be shaved and the skin properly sterilized A convenient hollow needle of the correct calibre to employ is a lumbar puncture needle sterilized by boiling It should be inserted in a backward and downward direction Once it is in place within the bladder the urine is drawn off with a 20 c c aspirating syringe

Suprapubic cystostomy is the best method of treating retention of urine due to spinal paralysis under average conditions If performed in a proper manner before infection has occurred by catheterization or neglect serious infection can be prevented In the past many were the cases in which cystostomy was performed only after serious infection had occurred via a catheter What is required is to disseminate the knowledge that cystostomy should be performed as early as practicable and not after catheterization has become inconvenient or in an attempt to remedy the ensuing cystitis

Cystostomy is an admirable form of relieving these patients and facilitating nursing If it is to be temporary the fistula can be closed readily at any date after the bladder has recovered its tone If it is to be permanent

Facts such as these can leave no doubt that the care of the bladder in cases of spinal injury is of fundamental importance. Once infection has been allowed to occur its eradication is difficult, if not impossible. The cardinal problem before us is to insist upon adopting measures to prevent such infection.

Before entering into a discussion as to the best methods of achieving this end, it must be realized that patients who can be received into a fully equipped hospital promptly after their injury and there receive efficient attention, may successfully tolerate methods which will be utterly unsuited to, say, a soldier who has to be transferred from the battle-field to a base hospital.

Let us examine the methods of bladder drainage which are available and evaluate them:—

1. Intermittent catheterization.
2. The tied-in catheter.
3. Expression of the bladder.
4. Aspiration of the bladder.
5. Suprapubic cystostomy.

Intermittent catheterization has proved a disastrous form of treatment. Even when an earnest endeavour is made to catheterize the patient with more than ordinary aseptic precautions, sepsis only too often supervenes eventually. For reasons stated already, the paralysed bladder is extremely vulnerable to the mildest infection. Seeing that the patient must be catheterized at four or six hourly intervals, it is almost beyond the powers of the most conscientious surgeon to organize a system which ensures that on *every* occasion the catheter is passed with the skill and the rigid ritual which is demanded. Under field conditions such a standard of perfection is quite unattainable, and if catheterization is permitted the following depressing type of cases will often be the aftermath.

An air mechanic who fractured his spine in the cervical region in September 1916 was transferred from France to the London Hospital three days later. By then the urine contained thick, ropy pus, and several false passages had been made in the urethra, although he had only been thrice catheterized. (Head and Riddoch.)

Intermittent catheterization can be advocated only when early recovery of bladder function is to be expected confidently and when the facilities and organization for super-skilful instrumentation are available. As bladder paralysis associated with spinal injury is neither of short duration nor a matter for precise prognostication, and as under war conditions ideal catheterization can seldom be maintained consistently, the method is one which for practical purposes should be ruled out of court.

The tied-in (syn. indwelling) catheter.—Sir John Thomson-Walker, in 1918, related his experiences as follows: "Cases arrived at the Star and Garter Hospital in which part of the urethral floor and overlying structures had sloughed at the peno-scrotal angle, leaving a gap of 1 to 2 in. as a result of combined urethritis and the pressure of the tied-in catheter." Such a result is unknown in ordinary urological practice and to a large measure it must be attributed to the associated trophic disturbances.

A many tailed bandage is admirable for keeping the dressings in place As soon as the patient is returned to bed the catheter is connected by a sterile junction to a water seal bottle beside the bed (see p 383) An important point is to ensure that the tube is not dragged upon A simple method of preventing this is to secure the tube after it has passed over the patient s thigh to the lower sheet of the bed by a safety pin in such a manner that there is ample play between the safety pin and the patient Instructions must be given that the patient must never be moved in bed for attention to the back or bowels or for any other purpose unless the suprapubic drainage arrangements are at the same time completely in view

CHANGING A SUPRAPUBIC CATHETER—The catheter can be changed without difficulty any time after the twelfth day for by this time the wound tract is lined with firm granulations If by some mischance the catheter becomes displaced and has to be changed before this time special precautions have to be taken A urethral catheter is passed and a tepid weak antiseptic solution is run through the urethral catheter and collected by a Hamilton Irving box temporarily placed over the cystostomy wound. While the lotion is flowing out a suitable de Pezzer catheter mounted on an introducer is passed into the bladder and manipulated into accurate position In ordinary circumstances there is no need to change the catheter for a month and if a Malecot catheter was used in the first instance it is well to replace it by a de Pezzer pattern as this gives a more watertight contact with the bladder once the tract is lined with granulations Wrapped in a towel the original catheter is pulled out and after the wound has been cleansed the new de Pezzer is introduced.

IRRIGATION OF THE BLADDER—If the urine is clean it is inadvisable to wash out the bladder during the stage of complete paralysis Tone usually begins to reappear after three weeks When this stage is reached an irrigation every two or three days is desirable This washes out any débris which may have collected at the base of the bladder and is an opportunity to ensure that the tube is in correct position and that its lumen is clear Irrigation is best done with a bladder syringe though a tube and funnel can be used By either method irrigation must be gentle and care taken not to over-distend the bladder 2 or 3 oz at a time being enough to run in during the stage of complete atony The bladder should not at any time be forceably distended A suitable wash is a solution of boracic acid a teaspoonful to a pint or potassium permanganate solution 1 4 000 or acriflavine 1 10 000 Solutions should be tepid, at a temperature of between 90° and 100 F In cases of severe alkaline cystitis with phosphatic incrustations the bladder may be first irrigated with a solution of acetic acid (B P) 1 drachm to a pint and this is subsequently washed out with boracic acid solution It may be useful to pass a urethral catheter to ensure thorough flushing from below out through the cystostomy tube

EXAMINATION OF THE URINE—The most important test is a daily naked eye inspection of a recently collected specimen of urine This should certainly never be omitted during the early stages of treatment If necessary a tablespoonful of 10 per cent acetic acid can be added to the urine to dissolve alkaline phosphates By this means the onset of cystitis should it occur can be as readily recognized and the progress of the case can be

I consider that its advantages considerably outweigh its disadvantages. The majority of patients confined by paralysis to bed and wheel-chairs are better served by a permanent cystostomy than by the automatic bladder, which has often been stated to be the best solution to this problem. A properly performed cystostomy can be relied upon to keep the patient dry and clean so long as it is allowed to function.

TECHNIQUE OF SUPRAPUBIC CYSTOSTOMY IN CASE OF SPINAL PARALYSIS—Even presuming that the bladder is full, as it should be, the operation is somewhat more difficult to perform on a paralysed bladder. For example in a case of retention due to prostatic enlargement, the contractility of the bladder is unimpaired, and the full bladder commonly forms a large and prominent swelling which is easily accessible when the abdominal wall has been incised. In retention occurring as a result of spinal paralysis the bladder is inert. Even though it contains two or three pints of urine, distension may not be obvious, as it falls back into the pelvis. It thus behoves us to obtain adequate exposure of the bladder wall and to take precautions that it is not allowed to collapse before the de Pezzer catheter is securely in place.

If the lesion is above the eleventh dorsal segment, no anæsthetic is necessary. Should an anæsthetic be required, it is best to employ general anæsthesia. Intravenous anæsthesia or gas and oxygen meet the case. Local anæsthesia, so satisfactory for this operation in other circumstances, may increase a risk of sepsis should the solution in part infiltrate paralysed tissues.

Especially in cases of complete paralysis, shaving must be conducted with particular gentleness to avoid traumatizing the skin. For the same reason the area of operation is cleansed with ether soap and then spirit or metaphen. Iodine or other antiseptics tending to blister are avoided, and particular care is taken that none of the antiseptic runs into the fold of the groin or on to the scrotum. If there is any doubt as to whether the bladder is full, and, as has been pointed out, the inert bladder tends to fall back into the pelvis, a catheter should be passed after the glans has been carefully cleansed and the urethra washed out with a bland antiseptic such as flavine solution. The bladder is then filled through the catheter with the same solution. Another indication for preliminary catheterization is when the urine is infected. Time spent in preliminarily washing out the bladder is well spent.

The bladder having been exposed through an adequate incision, it is picked up securely with two tissue forceps at points about 1 in apart. A de Pezzer catheter is then introduced by one of the accepted methods of suprapubic catheterization, *i e*, either through an appropriate trocar and cannula or by means of a bladder perforator, the object being to introduce a de Pezzer or Malecot catheter without urine escaping alongside the catheter. If the cystostomy is performed in this manner, no urine, or a very small amount, will be spilled and none will subsequently leak out. No sutures are necessary for the bladder. The cave of Retzius should be drained by a piece of corrugated rubber for forty-eight hours. Catgut sutures are used to unite the sheaths of the rectus muscles. The skin is approximated and one of the skin stitches is used to anchor the suprapubic catheter. In dressing the wound care should be taken to see that the tube is not kinked.

undesigned happenings occasioned by the slightest movement It requires but little imagination to foretell the practical outcome the patient keeps his penis in a urinal and an ascending infection therefrom is not always postponed indefinitely

As has been indicated if an automatic bladder is going to develop it often does so about the fourth week Causes which prevent or delay the advent of this phenomenon are severe and prolonged over-distension of the organ and serious cystitis The surgeon will not have much to do for the patient's urinary condition at this stage but he is likely to be called in —

(a) Regarding belated cystostomy in patients who have developed severe cystitis while awaiting automatism He can advise suprapubic cystostomy in these cases without the slightest hesitation

(b) To decide if it is advisable to allow a previously made cystostomy wound to close This question depends entirely on the spinal lesion In cases of total transverse lesion of the cord a properly conducted cystostomy opening is infinitely preferable to an automatic bladder and for reasons stated above the surgeon will strongly advise that suprapubic drainage should continue

In the case of lesions in the region of the lumbar enlargement or more especially of the cauda equina the position is entirely different Patients with injuries in these regions may be able to walk and even resume their occupations and therefore they wish to be quit of a permanent cystostomy As stated on p 357 such patients often attain a fair degree of control There is therefore every justification for allowing the cystostomy to close, providing no serious infection is present It is a wise course to warn the patient that closure of the fistula is an experiment and if he finds that control is unsatisfactory he will be better off by the re-establishment of suprapubic drainage

AUTOMATIC TIDAL DRAINAGE OF THE BLADDER

The method was originated by Donald Munro of Boston U.S.A It can be used via a tied in urethral catheter or a suprapubic de Pezzer catheter

Fig 307
Flute-tipped rubber catheter

If a catheter is to be tied in the urethra the best type to employ is a flute-tipped catheter size 16 or 18 Charrière this has one terminal and two lateral eyes (Fig 307) Tiemann's catheter is also suitable (Fig 308) Jaques catheters do not always drain well for they have a relatively small lumen and only one eye Silk web catheters should be condemned in cases of

Fig 308
Tiemann's rubber catheter

more readily assessed than by appeals for repeated pathological reports. Microscopy and culture of urine should, however, be carried out from time to time, samples being collected directly from the cystostomy tube for this purpose.

Urinary antiseptics.—In the absence of urinary infection none are necessary. The best treatment of cystitis, both preventative and curative, is cystostomy with irrigation if necessary and a continuous diuresis; under these conditions drugs are not often required. Hexamine, gr. x t.d.s., may sometimes be prescribed but the case should be watched carefully, for sometimes hexamine may cause hæmaturia. If there is severe alkaline cystitis, sodium acid phosph. gr. xx t.d.s., can be tried as a means of getting the urine acid. The reaction of this should be tested as the urine runs out of the cystostomy tube, not after it has been allowed to stagnate in a vessel. Sodium acid phosph. however sometimes causes diarrhœa, which is particularly to be avoided in these cases on account of nursing difficulties. The sulphonamides should also be tried, particularly in infections due to coliform organisms. Alternatively mandelic acid or one of its derivatives can be tried.

Closure of the suprapubic fistula.—Reflex micturition cannot occur unless the third and fourth sacral segments are intact, a matter which must be investigated by a neurologist before the suprapubic urinary fistula be allowed to close. A test of bladder automatism may be made by temporarily plugging the cystostomy tube. Observations are then possible as to the occurrence of micturition per urethram. Closure of the fistula should certainly not be allowed until bladder tone is recovered fully and until the risk of cystitis is minimal. A cystostomy tube should therefore remain in position for at least two months. As a rule, if the suprapubic catheter is removed after a week the fistula will heal spontaneously. During this period a suprapubic box is used to collect the urine. If closure of the fistula is delayed, a catheter tied into the urethra for a few days will expedite matters. In a few instances it is necessary to curette the fistula down to the bladder mucosa with a sharp spoon before the fistula will close.

ON THE AUTOMATIC BLADDER (SYN. REFLEX MICTURITION ACTIVE INCONTINENCE)

If bladder automatism is allowed to develop it often does so after a period of transition during the third or fourth week after the injury. The automatic bladder, once the pride and joy of the neurologist, is now generally considered a not unmixed blessing, either to the patient or to his attendants. Provision must be made for the bladder to empty itself at intervals from one-quarter of an hour to three hours. True, a few patients become semi-conscious of impending micturition, and fewer still are able to educate a reflex, such as tickling the inner side of the thigh, to initiate the act. Even intelligent patients belonging to this small favourable group, devoting much time and trouble to their automatic bladders, are not readily successful in getting the urinal into timely position. In the majority of patients the automatic bladder is truly automatic.[1] The patient does not know when he is passing urine. The initiating reflex is detonated by a host of filled the level of the fluid rises in the system to this height and then overflows the loop and runs down the tube to the receptacle emptying both the bladder and the tubing by siphonage The process then starts again automatically

The glass drip-feed must have a side tube which is left open The end of the outflow tubing must not dip into the fluid in the receptacle and there must be no air in the catheter nor the tube leading to it The tubing leading from the Y-shaped glass connection should be of larger bore than the other tubes When the automatic drainage has been proved to be working satisfactorily it can be allowed to function continuously The lotion used may be any bland bladder wash and it can be used cold

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paralysis because, owing to their stiffness, they are liable to cause pressure sores in the urethra. The catheter should be placed so that all its eyes are just within the bladder, and it is affixed to the penis with flexible adhesive plaster. The skin here must be watched very carefully in the subsequent stages of treatment. The position should be checked at the time of tying-in and soon afterwards, to ensure that the drainage is perfect. The catheter is then joined to the apparatus by a sterile connection. Great care must be taken at all times to ensure that there is no pull upon the catheter. The catheter is changed every three to six days, the urethra being irrigated before a new catheter is inserted.

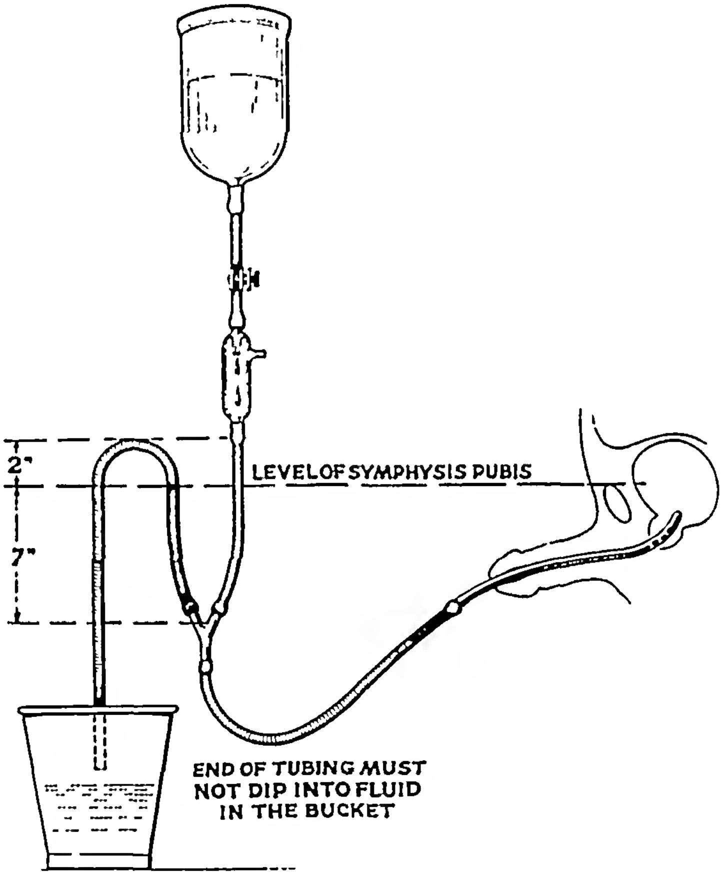

FIG. 309

Apparatus for tidal drainage of the bladder

(After Laurie and Nathan.)

Apparatus for tidal drainage—There are many modifications of the apparatus, of varying complexity (Fig. 309). By means of a reservoir and a drip-feed indicator with a regulating screw above it, the bladder is filled at a very slow rate; sixty drops a minute is what is usually suggested. A Y-shaped glass tube connects the inflow tube with the cystostomy tube or catheter, and by its other branch connects it also with a tube draining into a receptacle on the floor. This branch is at one point looped up to a certain height above the patient's symphysis pubis; *in cases of paralysis this height should be 2 in. only*. When the bladder has become

SECTION VIII

WOUNDS OF THE TRUNK

SECTION VIII

WOUNDS OF THE TRUNK

CHAPTER XXXV

WOUNDS OF THE THORAX

War injuries of the thorax are of two varieties —

1. Crushing injuries without external wound
2. Penetrating wounds

CRUSHING INJURIES WITHOUT EXTERNAL WOUND

An extensive crushing injury can occur within the thoracic cavity with but little damage to the chest wall. In children in whom the chest wall is elastic even the ribs may remain unfractured.

Most crushing injuries are associated with fractured ribs or ribs are dislocated at their junction with the costal cartilages Less frequently the sternum is fractured or dislocated and/or the scapula fractured

Occasionally several ribs are fractured at two points resulting in an excessively mobile chest wall which moves in and out during respiration This state of affairs is associated with considerable dyspnœa The treatment of this type of injury is to apply adhesive strapping in two or three overlapping layers extending over the mid line in front and behind. During the application care must be taken neither to force broken ends of the ribs into the lung nor to cause penetration of the skin

Damage to the lungs by bomb blast—Sudden death or bilateral pulmonary damage sometimes results from the bursting of a bomb near the victim Originally the pulmonary damage was thought to be caused by the positive or negative wave acting upon the air in the upper air passages and main bronchi. Zuckerman has demonstrated on experimental animals that these effects are produced by the compression wave upon the chest wall, and that protection of the chest wall prevents or limits the damage to the lungs

The main lesion appears to be bilateral pulmonary hæmorrhages of varying degrees. The chief symptom in survivors is the expectoration of frothy blood-stained sputum

Tension pneumothorax—Laceration of the lung or bronchi by fragments of broken ribs is apt to result in the continuous escape of air into the pleural cavity Obviously as the amount of air in the pleural cavity increases so the lung collapses correspondingly and eventually the mediastinum becomes displaced to the opposite side This leads to considerable dyspnœa and is associated with a high percussion note diminution or absence of breath sounds and displacement of the cardiac apex beat towards the opposite side

TREATMENT—Rapid relief is afforded by the insertion of a short wide bore needle through the chest wall into the pleura A suitable position for the puncture is the second interspace about 2 in from the edge of the sternum (Fig 310) Local anæsthetic should be injected before making the puncture The procedure may require repetition If the escape of air into the pleura is continuous and rapid, a better practice is to leave the needle *in situ* and connect it by suitable rubber tubing to a "water-seal" bottle

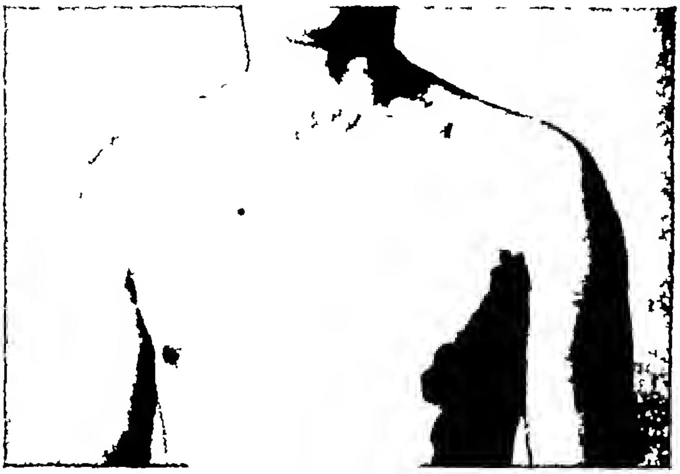

Fig 310

Tension pneumothorax The second interspace, 2 in from the lateral border of the sternum, is the best site for pleural puncture

Surgical emphysema—Two types of surgical emphysema are encountered in chest injuries—superficial and mediastinal

SUPERFICIAL SURGICAL EMPHYSEMA results from air escaping into the superficial tissues, (*a*) from laceration of the lung by indriven rib fragments, or (*b*) from penetration of the lung by a missile In many instances the air escapes into the subcutaneous tissues because the lung from previous disease is adherent to the parietal pleura In other cases the surgical emphysema is associated with a pneumothorax

The superficial tissues are swollen and finely crepitant on pressure When extensive, the condition may spread upwards to the face and neck and downwards over the abdominal wall and into the scrotum or labia, where, owing to the laxity of the subcutaneous tissues, considerable swelling often occurs In a few extravagant examples considerable discomfort is experienced and even difficulty in respiration encountered

MEDIASTINAL EMPHYSEMA usually results from injury to a large bronchus The escape of air into the mediastinum sometimes leads to obstruction of large veins, interferes with respiration and even deglutition In most cases the air gradually passes upwards through the superior thoracic aperture into the superficial tissues It then spreads in the superficial tissues of the neck and face When the opening into the bronchial tree is large and the escape of air into the mediastinal tissues rapid, death usually results quickly

X-RAY EXAMINATION gives a characteristic picture of the air in the tissue planes which tends to obliterate intrathoracic conditions Mediastinal emphysema will be shown by broadening of the mediastinum and the obvious presence of air therein

TREATMENT OF SURGICAL EMPHYSEMA—The majority of cases of surgical emphysema do not require any treatment In the course of a few days the air is absorbed When the condition is progressive and is causing symptoms, it is necessary to introduce a large needle into the subcutaneous tissues and to massage the air towards the needle through which it escapes In mediastinal emphysema, when the patient is getting worse, it may be advisable to carry out thoracotomy by the usual incision (see Fig 311) and incise the mediastinal pleura This permits the imprisoned air to enter the pleural cavity from which it can escape through an intercostal tube Any obvious bronchial laceration should be sutured.

THORACIC WOUNDS

The aims of treatment are :—

(a) Primarily to deal with the imperatively urgent conditions of shock, hæmorrhage tension pneumothorax and open pneumothorax

(b) Secondly to prevent or minimize sepsis which is the direct or indirect cause of practically all late morbidity and mortality

Immediate treatment—SMALL PENETRATING WOUNDS of the chest may show few or no acute symptoms, whereas others may cause symptoms of a similar nature to the non penetrating type When symptoms are absent emergency treatment consists in the application of a sterile dressing to the wound of entrance and exit where the latter is present

OPEN PNEUMOTHORAX (sucking wounds)—The most serious emergencies, apart from certain cardiac wounds in the survivors of wounds penetrating the pleura are those in which either the entrance or exit wounds are large enough (1) to permit the entrance of air during inspiration and to prevent its exit during expiration (valvular wounds) or (2) to permit the free entrance of air during inspiration and its exit during expiration (open pneumothorax) The former variety will give rise to a tension pneumothorax similar to that described already The latter type is associated with grave shock and dyspnœa an open pneumothorax is obvious on examination as blood and air are sucked into and escape from the wound during respiratory movements

Immediate treatment of sucking wounds —In either case rapid relief will be obtained by closure of the wound which should be carried out at the first available opportunity Any obvious superficial foreign bodies should be removed and the surrounding skin cleaned and painted with iodine When the loss of tissue is not extensive the wound should be closed by deeply placed silkworm gut sutures including if possible the underlying muscle and fascia Where facilities do not permit suture the wound should be dressed with sterile gauze or lint impregnated with an oily solution such as flavine paraffin emulsion covered widely by oiled silk and fixed by overlapping layers of adhesive strapping

The aim is to effect an air tight closure of the wound or wounds When a tension pneumothorax is present after closure it should be relieved by insertion of a hollow needle as described on p 369

Delay in these cases is disastrous—It will be noted that all the proceedings described above can be carried out under relatively difficult circumstances and this is fortunate for to be effective there must be no delay Elaborate clinical examination of the thorax can be deferred until the patient is received into a properly equipped hospital. As in other serious wounds morphia is a most valuable drug *it must be given in adequate doses* (up to ½ gr for a robust man) The necessity for warmth during transit must not be forgotten.

Examination and treatment of patients in hospital—If the above emergencies are treated before admission to hospital the first care of the patient is to treat shock and hæmorrhage as necessary To control dyspnœa and cyanosis, high percentage oxygen (up to 90 per cent) should be administered by the B L B mask (see p 32), or, if this is not available, by other methods such as the author's spectacle frame carrier

As a rule full examination should be deferred until some recovery has taken place, but the surgeon should be watchful, for deterioration of the patient's general condition in spite of resuscitatory measures may indicate continuous intrathoracic bleeding and demand urgent operation

The points of importance to record at the clinical examination are the physical signs of air or fluid in the pleura, the situation of the cardiac apex beat the temperature, pulse and respiratory rates and the blood pressure

X-RAY EXAMINATION—An X-ray examination of the thorax is invaluable The portable apparatus can be brought to the patient's bedside The comparison of an anteroposterior and lateral view will indicate the size of any retained foreign bodies and help in their localization The presence of blood or air in the pleura and any displacement of the mediastinum including the heart can be seen Likewise, any collapse of the contralateral lung should be visible

INDICATIONS FOR EARLY OPERATION—Providing they conform with the stipulations set out in Chapter X thoracic wounds, in common with other wounds, should be excised Excision of the wound applies to the thoracic wall, it does not necessarily entail opening the pleural cavity, for which there are special indications

The indications for early thoracotomy are —

1 Wounds which have been sutured temporarily or packed to control an open pneumothorax or tension pneumothorax
2 A penetrating wound which is accompanied by signs of persistent bleeding into the pleural cavity
3 Wounds associated with fractures of ribs or scapula, where indriven fragments or splinters of bone are probable
4 Penetrating wounds with large retained fragments of missile
5 Abdomino-thoracic wounds
6 In view of the presence of phosphorus in incendiary bullets, it may be advisable to remove all retained bullets (This is contrary to practice during the 1914-18 war)

CONTRAINDICATIONS TO THORACOTOMY—

1 Small clean penetrating or perforating wounds without signs of continuing hæmorrhage
2 Shock and the effects of hæmorrhage are contraindications only until they have been overcome
3 The presence of infected or non-infected hæmothorax unless associated with other indications for operation (This condition will be discussed later)

THORACOTOMY FOR EARLY WOUNDS

When the site of either the entrance or the exit wound permits adequate exploration, thoracotomy is performed through the one giving the better exposure Otherwise (e g wounds high in the chest) exploration is under taken through a fresh incision

(a) **Thoracotomy through the wound**—The operation is commenced by meticulous excision of all layers of the wound commencing with the skin edges and ending with the broken rib ends periosteum and pleura *A complete change of instruments and gloves is now necessary* The wound is enlarged by extending the incision along the line of the rib or the intercostal space involved If the rib was fractured and a portion has been removed usually it will be advisable to remove a further segment of the same rib after incising and reflecting its periosteum

If a separate incision is used for thoracotomy it is still necessary to excise and suture wounds of entrance and exit This is best deferred until the end of the operation

When the upper part of the chest is the site of the principal lesion the fifth rib bed or fifth intercostal space is the most useful avenue of approach whereas in lesions lower in the chest the sixth or seventh rib beds or inter spaces provide more convenient access

(b) **Separate thoracotomy**—When it is necessary to explore the chest through a fresh incision the best site is the postero lateral part of the thoracic wall over the sixth or seventh rib from its angle for wards for 6 or 7 in and passing round the lower angle of the scapula (Fig 311) The incision is deepened through the two musculo-fascial planes until ribs and interspaces are exposed. Tetra towels are then clipped to the skin edges In the majority of cases the pleural cavity should be opened by incision of the intercostal muscles and pleura throughout the length of the incision (Fig 312 a) It is essential to obtain sufficient exposure Inadequate access entails trauma to the chest wall by the hand and instruments A small portion (1 in) of the superjacent rib is removed behind the angle and the underlying intercostal vessels ligated and divided (Fig 312 b and c) In patients over forty especially where the chest wall is rigid it will be advisable to remove about 3 in of the rib and a small segment of the superjacent rib behind the angle and incise the pleura through the rib bed instead of the intercostal space (Fig 313) Linen tetras soaked in 1 1 000 proflavine should be employed to line the intercostal incision and are held in place by mechanical rib spreaders which are opened to give good exposure (see Fig 313 A)

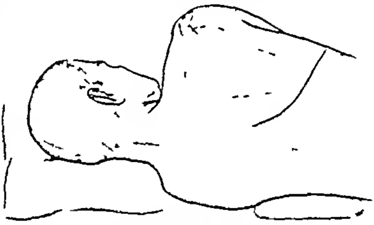

FIG. 311

The best site for designed thoracotomy is over the sixth or seventh ribs, as shown.

Intrathoracic procedures—When the chest is open fully the first step is to evacuate blood within the pleural cavity A suction apparatus is patient is to treat shock and hæmorrhage as necessary To control dyspnœa and cyanosis, high percentage oxygen (up to 90 per cent) should be administered by the B L B mask (see p 32), or, if this is not available, by other methods such as the author's spectacle frame carrier

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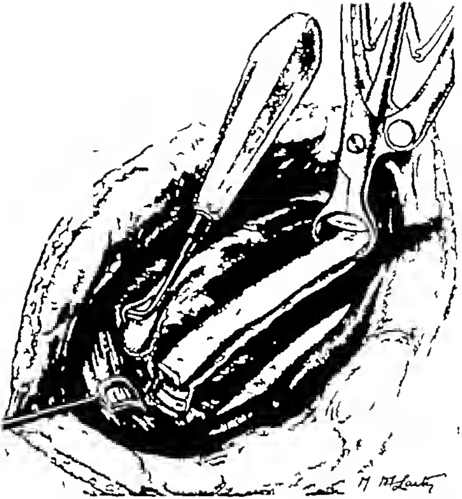

Fig 313
Stages of thoracotomy by extensive rib resection required in older subjects with rigid chest walls, viz., removal of long segment of rib below and of small segment behind angle of rib above. Pleura opened by incision of rib bed below.

this time within the wounded lung Unless the lung is damaged severely (see below) it can now be sutured, either by continuous or interrupted stitches in one or two layers as necessary to obliterate dead spaces

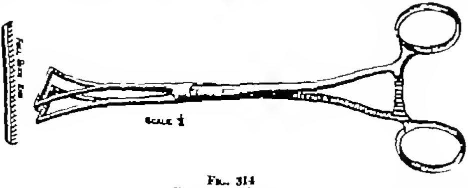

Fig. 314
Duval's lung forceps.

TREATMENT OF LACERATED LUNG—Lacerated portions of lung should be excised. When the major portion of a lobe is pulped, lobectomy should be invaluable for this purpose Soft clots are removed by forceps rather than by swabbing, which tends to irritate the pleura and thus to increase post-operative pleural secretion Once blood and blood clot have been removed the search is made for foreign bodies—metal, rib splinters or pieces of clothing For this important search good illumination is essential, either a spotlight, or one of the many excellent patterns of sterilizable wound illuminators is employed to scrutinize the pleural cavity, especially the

Fig 312

Thoracotomy by intercostal incision and resection of 1 in of superjacent rib behind angle after displacement backwards of erector spinae muscle Subsequent stages are similar to thoracotomy following resection of long segment of one rib

costophrenic sulcus Attention is then directed to the lung itself To prevent further contamination the pleural cavity around the collapsed lung is packed lightly with gauze wrung out in 1 1,000 proflavine Grasping the lung with Duval's forceps (Fig 314), the site of the entrance of a retained foreign body is brought under vision

In recent wounds, now being considered the track is seen and explored easily Usually the foreign body can be extracted through its own track, but if this proves difficult, the point is chosen where the foreign body lies nearest the surface of the lung and a direct incision is made upon it Having removed the missile by one or other of these manœuvres, once again a careful search is conducted for bone splinters and pieces of clothing, and pleura respectively and the layers of muscles and fasciae of the chest wall are sutured with continuous catgut and the skin and subcutaneous tissues with interrupted sutures of silkworm gut or proofed silk. In wounds with extensive loss of tissue it may be necessary to slide muscles or to dissect a muscle flap from an adjacent area to close the wound.

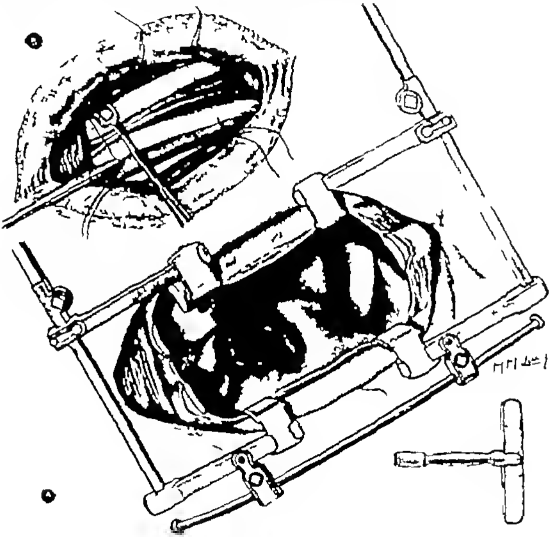

FIG. 313

A, Exposure of intrapleural contents by insertion of chest-wall retractors. Lung is drawn into wound by application of Duval's lung forceps.
B, Insertion of pericostal sutures and approximation of ribs by retractor. After tying pericostal sutures periosteum and pleura are sutured in one layer.

A layer of sterilized gauze is placed along the incision and another portion split to enclose the drainage tube. Over this overlapping layers of adhesive plaster are applied as in the case of fractured ribs.

Lastly the Malecot's tube should be connected by intermediate tubing to a "water-seal" bottle. It is not sufficient to allow a piece of tubing to hang into fluid in an open mouthed bottle as this will permit air to enter the pleura if the tube is dragged upon sufficiently to pull it out of the fluid.

undertaken. When it is the lower lobe which is concerned, the ligamentum latum pulmonis is divided up to the inferior pulmonary vein and bleeding vessels ligated. A tourniquet is applied to the hilum and tightened, taking care not to include or otherwise damage the pericardium. The lung distal to the tourniquet is excised with scissors. The cut vessels and bronchi of the hilum are closed by mattress sutures of fine thread or catgut. After loosening the tourniquet, remaining bleeding points can be seen and ligatured. When the hilar vessels have been controlled, the tourniquet is removed and the fringe of pulmonary tissue covered by its visceral pleura is approximated so as to cover the raw surface.

Difficulties may arise when the interlobar fissures are incomplete. In such cases the hilar end of the lobe must be freed from the adjacent lobe by careful dissection.

The procedure for the upper lobe is similar, omitting the division of the ligamentum latum pulmonis.

TREATMENT OF FOREIGN BODIES IN THE MEDIASTINUM

It is usually inadvisable to attempt to remove small foreign bodies which have passed through the pleura into the mediastinum. When large foreign bodies are present, they are almost certain to cause trouble later, and an attempt should be made to remove them. Occasionally a foreign body becomes embedded in the walls of a large vein. If the missile is extracted without controlling the vessel on its cardiac side, fatal air embolism is prone to occur. Therefore, where possible, before attempting to remove such a foreign body it is of paramount importance to dissect the vein on the proximal and distal sides, and to pass beneath each a length of thread. If these are held taut while the foreign body is removed, hæmorrhage and air embolus are prevented. The method permits lateral suture of the opening in a large vein.

DRAINAGE OF THE PLEURA

Air-tight drainage of the pleura maintained for three to four days after thoracotomy is very unlikely to lead to infection from without. It has certain advantages in that (1) it provides an outlet for any further blood and fluid effused into the pleura, (2) it permits the escape of the air from the pleura after operation, and thereby aids expansion of the lung and prevents air escaping into the layers of the chest wall through the operation wound during coughing (surgical emphysema). This is of considerable importance, as infection may be carried from the pleura into the chest wall, causing infection therein and possible breaking down of the wound. (3) It does away with the necessity of repeated aspirations of the pleura during the first three to four days.

The drainage should *never* be carried out through the wound but by the intercostal insertion of a Malecot's tube, preferably through the ninth interspace at the angle of the rib. A small skin incision is made in this situation and a trocar and cannula introduced into the pleura. The trocar is withdrawn and the catheter stretched on an introducer and passed through the cannula, which is withdrawn, leaving the tube in position. The tube should be adjusted so that the openings lie just inside the pleural cavity and the outside of the tube should be anchored to the skin by a stitch.

Closure of the incision—Whether the exploration has been carried out through the periosteal bed of a resected rib or through an intercostal space, the ribs above and below the incision are approximated by the insertion of three pericostal sutures (Fig. 315, B). The intercostal muscles or periosteum with overlapping strips of adhesive plaster In many cases it is possible to carry out delayed primary suture of the wound in four to five days

The necessity of more wide exploration of the chest at the time of treatment of the wound will depend upon such factors as the presence of a large foreign body requiring removal widespread damage to lung tissue etc The essential is to obtain pulmonary expansion at the earliest possible time so that suppuration is limited to as small a pleural pocket as possible

HÆMOTHORAX

There is little difference in the early stages between hæmothorax due to crushing accidents and wounds of the chest The former may become infected from the lung or from the blood stream but infection is much less common than in penetrating wounds where the incidence of infection during the 1914-18 war was as high as 25 per cent

It is interesting that cases of perforating through and through wounds of the lung are occasionally encountered in which no obvious hæmothorax is discoverable either by clinical or radiological examination although a definite hæmatoma of the lung can be seen.

In all cases of hæmothorax there will be signs of fluid in the pleura *i e* dullness on percussion diminished vocal fremitus but where the layer of fluid is not considerable there may be bronchial breathing and increased vocal resonance on auscultation sometimes resulting in a diagnosis of pneumonia In larger effusions breath sounds and vocal resonance will be absent over the effusion and Skodaic resonance will be apparent above Displacement of the cardiac apex beat to the opposite side is always present except in very small hæmothoraces or when massive collapse of a lobe or the lung is associated

The temperature may be raised as high as 103 in uninfected cases it generally falls within a few days but takes longer to settle in the larger effusions.

In both closed and open wounds of the thorax a hæmothorax may be associated with the presence of air which has entered through the chest wound or escaped from the lacerated lung—hæmopneumothorax

X ray examination—The appearances shown by X rays in cases of hæmothorax will vary according to circumstances When air is not present there will be a diffuse shadow involving a varying amount according to the extent of the effusion of the normally translucent lung and extending from the base upwards In the larger effusions displacement of the heart can usually be seen but if there is considerable pulmonary collapse beneath the effusion the displacement may be very little or absent

It is common to find the diaphragm displaced upwards even in cases in which massive collapse is absent and this condition is probably due to patchy atelectasis insufficient to cause mediastinal displacement to the affected side Unless this fact is recognized it is possible at operation to enter the abdominal cavity inadvertently The administration of a small dose of sodium bicarbonate before radiological examination will demonstrate the position of the diaphragm on the left side by the visualization of the bubble of gas in the stomach

ABDOMINO-THORACIC WOUNDS

Missiles penetrating the lower chest during the inspiratory phase may lacerate the diaphragm without obvious evidence of abdominal injury Tangential wounds of the lower chest may also produce considerable laceration of the diaphragm either from the missile or from the fractured ribs, and in some of these cases the omentum may be seen prolapsed on the lower chest wall Similarly in oblique wounds, the missile may pass from the chest into the abdomen or vice versa, the missile passing out or being retained in chest or abdomen

When the missile has only penetrated the upper abdomen and chest, it is advisable to carry out a thoracotomy first and to explore the upper abdomen by enlarging the opening in the diaphragm The thoracotomy should be carried out at a lower level than usual, *i e* about the level of the eighth rib Repair to stomach, colon and even splenectomy were carried out through the diaphragm on many occasions during the 1914-18 war

If the missile is retained or has passed in or out of the lower abdomen, primary laparotomy will be required The chest may or may not require operation, apart from excision of the wound of the chest wall, according to circumstances

In all cases the wounded diaphragm should be closed by sutures of silk or linen thread after excision of the edges of the laceration In order to limit movement of the diaphragm during the period of healing it is advisable to crush the phrenic nerve by a hæmostat as it passes on to the diaphragm

In cases where there is a loss of a portion of the lower thoracic wall, it may be possible after excision of the wound edges in the parietes and diaphragm to suture the latter to the chest wall above the deficiency, thus shutting off the pleural cavity from the outer air The diaphragm is also sutured completely if the subdiaphragmatic injury permits, or sufficiently completely to drain the upper abdomen through it if the injury in the abdomen makes drainage necessary

Abdomino-thoracic wounds are usually associated with a high mortality but much depends upon the severity of the injury especially to hollow viscera

TREATMENT OF THORACIC WOUNDS OF OVER EIGHTEEN TO TWENTY-FOUR HOURS' STANDING

Infection seriously complicates wounds in which considerable loss of the chest wall and open pneumothorax is present The wounded lung is collapsed and relatively solid with effused blood This prevents the lung being pulled up and sutured to the chest wall, which is a useful expedient for closing the pleural cavity in early cases of this kind Again, to open fresh tissue planes to infection by swinging over muscle flaps to close the gap is absolutely contraindicated So it comes about that after a limited operation comprising wound débridement (see p 105) the best method is to pack the wound with gauze impregnated with powdered sulphonamide An intercostal tube is inserted at the site of election (ninth interspace posteriorly), and as described for other thoracic operations, the operative area is well covered

Obviously if the collapse of the lung results in arresting the hæmorrhage it is most unwise to permit rapid pulmonary re-expansion

During the 1914-18 war aspiration was only advised in cases of large effusions of blood, especially those causing circulatory or respiratory embarrassment It was rarely performed before seventy two hours after injury Apart from this indication there is still a tendency to avoid aspiration because of the supposed risk of introducing infection

Let us examine the disadvantages of allowing blood to remain in the pleural cavity —

1 There is the risk of sepsis developing in an excellent medium
2 Even a thin film of clot tends to result in fibrosis of the pleura
3 It is extremely difficult to determine accurately whether intrapleural bleeding has ceased for apart from signs of general loss of blood the lung may progressively collapse without any gross increase in dullness to percussion or of the shadow shown on radiological examination.
4 Blood in the pleural cavity often hides shadows of foreign bodies which otherwise would show on radiological examination

Air replacement of a hæmothorax—The replacement of blood in the pleura by air should overcome all the objections to early aspiration This may be carried out as soon as shock and the effects of blood loss have been overcome and the patient has arrived in a hospital where aseptic conditions are possible

A stout hollow needle connected to a pneumothorax apparatus is inserted into the upper part of the pleural cavity (see Fig 310) A second needle connected to a syringe is inserted lower down posteriorly As the blood is aspirated from below an equivalent amount of air is permitted to enter the pleura from above thus preventing any expansion of the lung during aspiration Aspiration and air replacement are of course unnecessary in cases which are to be submitted to early open operation

Rapid reaccumulation of blood in the pleura suggests bleeding from vessels of the chest wall intercostal or internal mammary vessels and provides an urgent indication for open operation. In some cases one aspiration will be sufficient but in others it may be necessary to repeat it on several occasions owing to reaccumulation of fluid secreted by the pleura It is rarely advisable to employ air replacement after the first aspiration

INFECTED HÆMOTHORAX

A hæmothorax which has not been aspirated early sometimes shows no evidence of infection for many days when signs of infection appear quite suddenly Pyrexia may or may not be a feature but when it is present it tends to be irregular Pallor sweating and furred tongue and when gas forming anaerobes are present dyspnœa are often noted

In the early stages of infection it is not uncommon to find the upper part of the fluid sterile whereas aspiration at a lower level will show evidence of organisms A purplish colour and offensive odour of the fluid aspirated are signs of frank infection.

Radiological examination shows an increase in the effusion and when

When air is present in addition to blood a clearly defined fluid level may be seen in the radiograph This fluid level will alter as the posture of the patient is varied A large hæmothorax often conceals the presence of an opaque foreign body of considerable size unless the radiograph is of the penetrating type The appearances given by radiographs may be entirely different when taken in the erect position than when the patient is supine

It is therefore advisable that all radiographs should be clearly marked with regard to the position of the patient when the exposure is made but the most generally valuable are anteroposterior and lateral views in the erect position

A B

Fig 316

Radiographs of chest, showing right hæmothorax

A, Before aspiration B, After one aspiration

A B—Appearance suggestive of diaphragmatic hernia due to fibrin masses and air pockets in B

The appearance of radiographs of hæmothorax cases in which aspiration has been delayed for several days, and in which air is also present either because of its entrance during previous aspiration or by previous escape from the lung, is not unlike those produced by intestine herniated through the diaphragm Multiple fluid levels associated with localized pockets of air in the fibrinous masses are responsible for this appearance (Fig 316, A and B)

Treatment—Hæmothorax and hæmopneumothorax result in partial collapse of the lung, depending to a large degree on the quantity of fluid and air in the pleural cavity When the source of hæmorrhage is the lung itself the collapse will tend to lessen the hæmorrhage

As a rule, blood does not clot to the same extent as in other situations, although a thin layer of clot is often found over the diaphragm and lower intercostal area It has been suggested that the fluidity of the blood is caused by defibrination due to whipping by respiratory movements, but this is certainly not invariably the case, as often such blood clots after it has been aspirated Also, it is not uncommon to find soft clots in the pleura at thoracotomy

Obviously if the collapse of the lung results in arresting the hæmorrhage it is most unwise to permit rapid pulmonary re-expansion

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A B

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A, Before aspiration. B, After one aspiration.

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Treatment.—Hæmothorax and hæmopneumothorax result in partial collapse of the lung, depending to a large degree on the quantity of fluid and air in the pleural cavity. When the source of hæmorrhage is the lung itself, the collapse will tend to lessen the hæmorrhage.

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gas forming organisms are present a tension hæmopneumothorax is revealed by displacement of the mediastinum—heart trachea etc

Early treatment—In the milder infections repeated aspiration associated with the administration of sulphapyridine may be sufficient to clear up the infection In the acute forms especially those in which gas producing organisms are present the danger of a spreading cellulitis of the chest-wall as a result of repeated aspiration may be prevented by making a vertical incision at the point of election through skin and muscles down to the ribs The wound is packed with paraffin flavine gauze which is removed and replaced before and after each aspiration

A specimen of each aspiration is kept in a test tube and when after standing for twenty four hours the solid purulent deposit occupies three-quarters to seven eighths of the tube tube drainage should be instituted Drainage may be by intercostal tube or after rib resection. If the former is adopted in many cases rib resection will be required later Intercostal drainage is carried out by the introduction of an intercostal trocar and cannula into the ninth inter costal space posteriorly under local anæsthesia (1 per cent procaine) (Fig 317) The trocar is replaced by the tube stretched out on an introducer the withdrawal of the cannula over the tube end removal of the introducer leaves the tube in position (Fig 318) The tube is attached to a water-seal drainage bottle and no air should be permitted to enter the chest subsequently when the bottle is emptied each day the tube into the chest should be closed with a clip (Fig 319 C) Resection of a portion of rib and open drainage at this stage will lead to high morbidity and mortality and is a gross violation of the elements of chest physiology

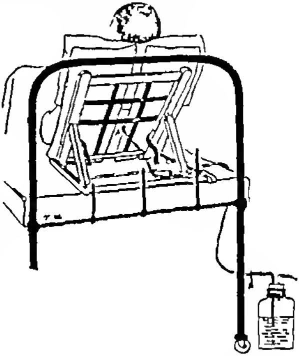

FIG. 319

Arrangement of bed rest and pillows to maintain free drainage from intercostal tube or after resected rib. This permits free up and down movement of the patient in the bed without interference with drainage. Note the water-seal drainage bottle

Later treatment—In the course of time the discharge gradually thickens which is an indication of the formation of a localized pocket of varying size surrounded by pleural adhesions

Persistence with intercostal drainage in many of these cases will result in the formation of a chronic empyema and therefore it is essential to review from time to time the *size of the cavity by radiological* examination even when the temperature and pulse may be relatively normal. Unless the cavity is decreasing rapidly in size more adequate drainage must be instituted.

This entails resection of a small portion of the rib above the intercostal

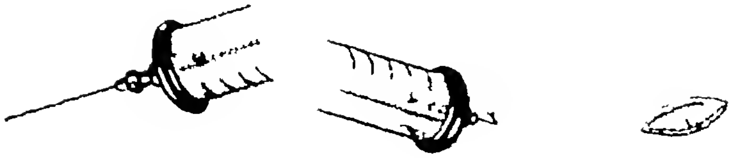

FIG 317
Local anaesthesia for intercostal drainage
1, Intracutaneous wheal 2, Deep infiltration 3, Incision of skin

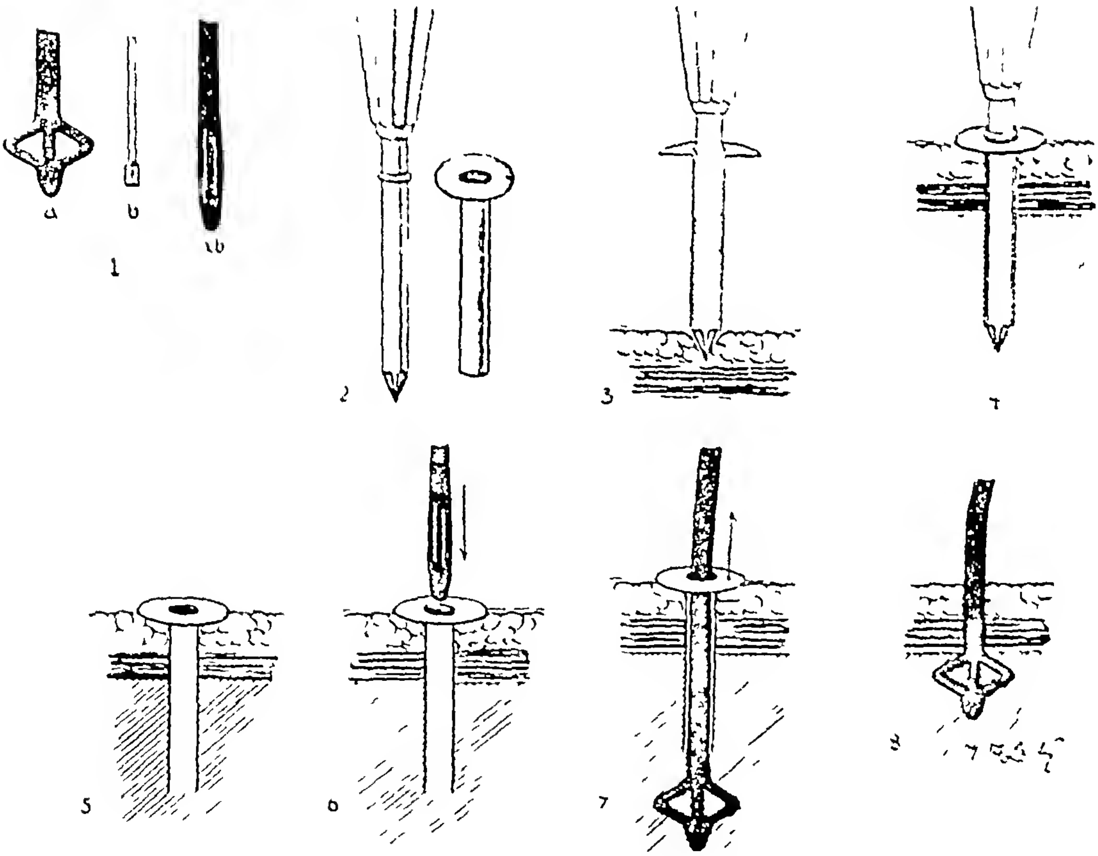

FIG 318
Intercostal drainage by Malecot's tube

1, (*a*), Tube expanded (*b*), Introducer
(*ab*), Tube stretched by introducer
2, Trocar and cannula
3, 4, } Trocar and cannula introduced after small incision in skin
5, Withdrawal of trocar
6, Introduction of tube stretched on introducer
7, 8, } Cannula and introducer withdrawn leaving tube *in situ*

of thick mucus plugging the main or lobar bronchi cannot be doubted and in this group rapid and striking improvement will result from bronchoscopic aspiration

This procedure can always be carried out most efficiently under local anæsthesia and entails only slight strain on even a seriously ill patient It should therefore always be undertaken when massive collapse is diagnosed and confirmed by radiological examination

CARDIAC AND PERICARDIAL WOUNDS

A proportion of patients with wounds of the pericardium and heart survive sufficiently long to reach hospital. Conditions will vary according to the ability of the blood to escape from the pericardium. When escape to the outside or into the pleura is possible the *signs will be those of hæmorrhage* associated in many cases with a friction sound due to the presence of blood in the pericardium In other cases the escape of blood from the pericardium may be so slow that accumulation (hæmopericardium) occurs and obstructs the cardiac action (cardiac tamponade) In such cases the venous pressure rises the arterial pressure falls and heart sounds become muffled

Occasionally neurological symptoms such as partial or complete hemiplegia have been described as secondary to the cerebral venous congestion produced by obstruction to the superior vena cava and auricles by the blood in the pericardium. It may lead to considerable difficulty in diagnosis

The indications for operation in wounds of the heart and pericardium are (1) hæmopericardium with cardiac tamponade (2) the presence of foreign bodies, more particularly irregular shell fragments impacted in the pericardium in the walls of the heart or within the cavities of the heart (3) pericarditis

Exploration of the pericardium—This should be carried out by a resection of the 3rd, 4th and 5th costal cartilages of the left side and if necessary portions of the corresponding ribs (or by an anterior intercostal incision in the fifth interspace which entails a transpleural exposure of the pericardium) *If the entrance or exit wound is in this area the edges should be* carefully excised, instruments and gloves changed and the wound enlarged If the pleura is intact it is carefully separated from the front of the pericardium by gauze dissection and displaced to the left The pericardium is opened and the blood evacuated. Pressure of the finger over the wound in the heart muscle will permit the insertion of sutures parallel to the wound. These are crossed the one over the other and held while deep sutures are placed and tied, closing the laceration When contamination of the wound is minimal and excision has been carried out early the pericardium should be completely sutured and a small piece of rubber tissue left in the lower end of the superficial incision for twenty four hours the remainder being sutured

If there is an opening from the pleura into the pericardium the edges of the wound should be excised and in suturing the pericardium enough space should be allowed between the sutures to permit fluid forming in the pericardium to escape into the pleura whence it may be aspirated

Operation is more urgent when fragments of shell are retained, owing to the frequency of fatal results from infection than when a rifle bullet is the cause of the damage drainage opening, removal of infected fibrin masses in the empyema and the insertion of a flanged tube (Fig 320). This is connected to a bottle as before. In the absence of a gross bronchial fistula, irrigation with Dakin's solution or eusol through the small side tube is carried out several times daily

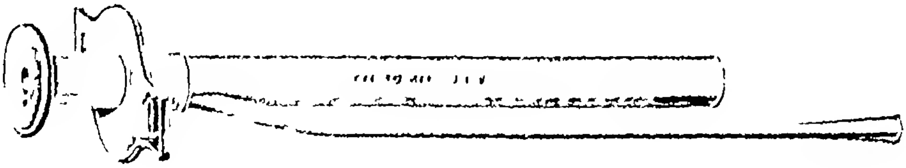

Fig. 320

Empyema drainage tube, Tudor Edwards, with adjustable flange

Continuous negative pressure drainage up to 5 cm can be instituted by means of a suction pump and special bottle fitted with a manometer (Roberts) This method will increase the rapidity of closure of the cavity

Early pulmonary expansion is assisted by the use of respiratory exercises as devised by McMahon directed to the re-education of the abdominal and intercostal musculature

The value of high carbohydrate intake, of slow-drip blood transfusions, and of treatment in the open air when weather conditions permit cannot be too highly stressed

The gradual diminution in size of the empyema cavity can be roughly judged by the amount of fluid it will retain when filled in such a position that the drainage opening is uppermost It is necessary however, from time to time to fill the cavity with radio-opaque oil (neohydriol) and to take anteroposterior and lateral radiographs

If recurrence of the empyema is to be avoided the tube should not be finally removed until the cavity is completely obliterated Careful treatment and repeated reassessment of the local and general condition of patients with residual empyema will result in fewer cases of chronicity and will largely eliminate the necessity for gross plastic procedures on the chest wall with their subsequent limitation of vital capacity and relative deformity.

COMPLICATIONS OF CHEST WOUNDS

Apart from the occurrence of infected effusions, *broncho-pneumonia* is one of the more common sequelae of chest wounds, but it is largely an indirect result of loss of blood prolonged exposure or general sepsis Lung tissue itself appears to have a relatively high resistance to the spread of wound infections and as a result gas gangrene and even local abscess are comparatively rare complications On the other hand, infective pericarditis is by no means rare even when the pericardium itself is primarily uninjured.

Massive collapse Massive collapse of a lobe or the whole lung is a recognized complication of gunshot wounds it may occur in the homo- or contralateral lung and in the latter case may prove a serious menace to life Various theories have been put forward such as reflex action, bronchial obstruction etc That a certain proportion is due to the presence

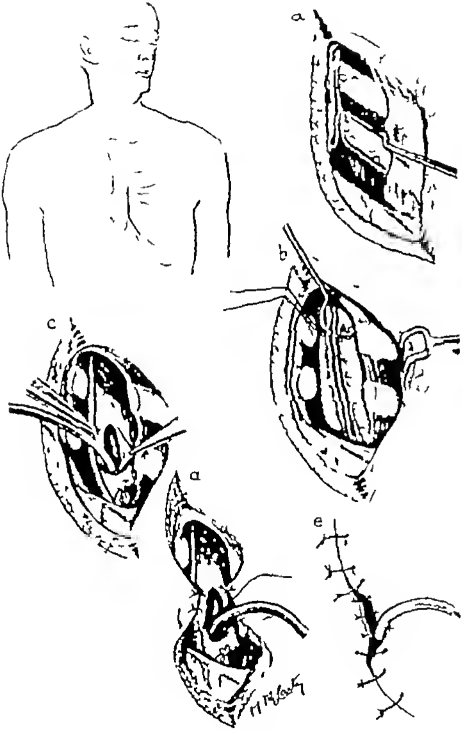

FIG. 321

Drainage of pericardium

a, Exposure of costal cartilage and reflection of perichondrium.
b Ligature of internal mammary vessels.
c, Pleura reflected, pericardium incised and catheter inserted.
d Suture of edges of pericardial incision to skin.
e, Suture of remainder of wound.

It was found during the 1914-18 war that missiles within the heart chambers will only remain *in situ* so long as the patient lies quiet and maintains the supine position. As embolism of the pulmonary artery appeared a probability when the missile was in the right ventricle, prompt operation was advised. On the other hand, as a foreign body in the left ventricle is likely to cause embolism of the subclavian, axillary or iliac vessels, and its removal from these vessels is less dangerous than removal from the ventricle, it is probably wiser not to operate on the heart.

The only method of diagnosis of the position of the foreign body is by means of X-rays, and as the localization may offer considerable difficulties as to which ventricle contains the foreign body the question is academical rather than practical.

Pericarditis—Pericarditis secondary to penetration of the pericardium or to an infected hæmothorax necessitates early operation if success is to be attained.

The diagnosis may be by no means easy when there is an associated infected effusion in the pleura, as this may disguise the enlargement of the heart shadow as seen by X-ray examination, and may be thought to account for a rapid pulse rate and a raised temperature. Replacement of the effusion in the pleura by air should enable the outlines of the cardiac shadow to be visualized in a radiograph, although pleural thickening tends to limit the value of this measure. In the majority of cases of pericarditis complicating empyema, there is no obvious increase in cardiac dullness and no diminution in cardiac sounds as the heart is rotated forwards from its fixed base towards the chest wall by the fluid behind it. The most important sign is the occurrence of a pericardial friction sound which is often only present for a few hours, and easily missed unless regular auscultation is carried out.

The diagnosis is confirmed by aspiration of turbid fluid or pus from pericardial puncture, carried out under local anæsthesia through the angle between the xiphisternum and the costal margin, the needle being inserted at an angle of 45° from the surface.

Drainage of the Pericardium (local anæsthesia, 1 per cent procaine)—The operation is carried out through a vertical incision just external to the left sternal margin. Portions of the 4th and 5th costal cartilages are removed, the internal mammary vessels ligatured above and below and the left pleura displaced outwards to expose the pericardium. After incision a fine catheter is passed behind the heart and all pus and flakes are washed out with saline. The opening in the pericardium should be at least 1 to $1\frac{1}{2}$ in long and its edges should be sewn to the skin (Fig 321). The catheter is fixed *in situ* by a suture, the wound left partially open and dressings applied. Subsequently the pericardium is washed out by instillation of 1 to 2 oz of saline at four-hourly intervals. Dakin's or eusol solution should *not* be used, as they are very irritating to the pericardium and cause cardiac irregularity and occasionally stoppage. Sulphanilamide in greater quantities than those required for prophylaxis should be given and a change may be advisable to sulphapyridine.

The irrigating catheter is not finally discarded until it comes out and it is impossible to replace it.

CHAPTER XXXVI

ANÆSTHESIA IN THORACIC INJURIES

BEFORE the anæsthetic is chosen an estimation should be made of the general condition of the patient The effect of any treatment already given for shock or hæmorrhage should be noted and supplemented if necessary by further measures The significance of cyanosis if present should be determined Cyanosis may be due to sulphanilamide prophylaxis to the administration of opiates for pain relief or to traumatic impairment of respiratory function All three factors may play a part in a given case but when a sulphanilamide alone is the cause the condition will respond to methylene blue (*q v*) Cyanosis due to opiates alone is not accompanied by dyspnœa It will respond to administration of oxygen and coramine When trauma is the cause however dyspnœa will be present in addition It is of particular importance in such cases that the anæsthetic should cause no *further impairment to oxygen intake* When continuous oxygen is being given care should be taken that administration is not interrupted during transfer from bed to operating theatre

Preliminary medication—Omnopon and scopolamine in a suitable dose is the best combination, due consideration being given to the effect of opiates already administered for pain relief

Local and/or regional anæsthesia is the method of choice when conditions permit of the injections being carried out satisfactorily This applies equally to penetrating wounds and crushing accidents as thoracic viscera are relatively insensitive to pain stimuli

Intravenous anæsthesia with pentothal is a useful supplement to local anæsthesia in certain cases Where local anæsthesia is impracticable pentothal can be used alone with advantage for operations of under one *hour's duration in patients over ten years* old The needle should be kept in the vein and successive small doses given as indicated The available operating time under pentothal depends largely on the rate of detoxication. In resistant individuals it is preferable to change over to inhalation anæsthesia rather than to exceed a dose of 1½ gm. of pentothal.

Pentothal contains a sulphur radical and caution *must* be *observed in* its employment in cases under treatment with a sulphanilamide So far however no bad effects have been reported when pentothal has been given to a *patient under sulphanilamide* treatment

Inhalation anæsthesia—Here certain precepts must be borne in mind. Since recent thoracic wounds require respiratory quiescence as opposed to hyperactivity any agent or method which stimulates respiratory activity should be avoided This applies to irritating vapours and to CO_2

LATE OPERATIONS

The question of operation in the later stages, after wounds have healed, may arise particularly when foreign bodies are present The decision will necessarily depend upon the nature and severity of symptoms These comprise rapidity and irregularity of cardiac action, dyspnœa, retrosternal pain, etc

A note on methæmoglobinæmia with special reference to thoracic cases— Methæmoglobinæmia produces cyanosis, and as this condition occasionally follows the administration of the sulphonamides it may lead to confusion with the other causes of cyanosis associated with chest wounds Methæmoglobinæmia can, however, be rapidly relieved in forty-five minutes by the intravenous administration of methylene blue (0 1 to 0 2 c c of 1 per cent aqueous solution per kilo body-weight) Given by mouth it acts more slowly and requires bigger dosage (0 5 to 1 gm per day) to produce effect

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accumulation The explosion risk must also be considered when diathermy apparatus is in use

Simple inhalation anæsthesia has still a place in chest surgery In this category chloroform and oxygen may prove at times to be the most useful combination It is non-irritating and non-inflammable

When a gas-oxygen machine is available, it is important when using it in cases of extensive thoracic injury to avoid cyanosis Thus, if a high percentage of oxygen be used with nitrous oxide an adjuvant may be necessary

When diathermy is not in use the adjuvant may be vinyl ether, cyclopropane or even ether in small quantity With diathermy, however, chloroform is the only adjuvant permissible

Cyclopropane—While this gas gives good results in the hands of some experts it is not to be generally recommended The cardiac irregularities associated with it have not as yet been assessed clearly, while its explosive nature rules it out when diathermy is used

Whatever the anæsthetic machine, an efficient soda-lime cannister should be incorporated Without proceeding actually to the state known as "controlled respiration" the cannister prevents excessive accumulation of CO_2 when the apparatus is not strictly closed

The value of *positive pressure* is debatable Where formerly it was held that positive intrapulmonary pressure is essential in the presence of open pneumothorax, experience shows that in many cases it is unnecessary In some cases positive pressure of a few millimetres of mercury is useful in stabilizing the mediastinum Higher positive pressure than this is not only needless but frequently dangerous Blood may be forced in this way into unaffected parts of the bronchial tree There is also a risk of mediastinal emphysema

It is essential in general anæsthesia to maintain a free airway at all times, but intubation is unnecessary in the majority of operations Intubation should be reserved for those operations during the course of which it may be necessary to aspirate blood from the trachea or bronchi The endotracheal tube should be as large as possible to allow the suction catheter to pass easily thiought it

After the withdrawal of the anæsthetic, in all chest operations of gravity it is imperative to begin oxygen administration at once and not to delay this as is commonly done until the patient has returned to the ward

CHAPTER XXXVII

THE EVOLUTION OF THE ABDOMINAL SURGERY OF WAR

SURGICAL MILESTONES

IN 1881 when laparotomy was in its earliest infancy Marion Sims (Fig 322), the American surgeon so well known as the inventor of Sims speculum, advocated and practised surgical intervention in gunshot wounds of the abdomen if there was reason to believe that viscera had been damaged. The results were disappointing, but he demonstrated the possibilities of a successful issue in otherwise hopeless cases.

Between 1803 and 1899 the problem of the treatment of abdominal war wounds became the subject of widespread and often acrimonious discussions. Military surgeons became divided into two schools—the interventionists and the abstentionists. The interventionist comprised the smaller

Fig 322

James Marion Sims (1813-83)

During the American Civil War for political reasons he moved to Europe and resided in London and Paris for six years.

Fig 323

Paul Réclus (1847 1914) Surgeon to the Paris Hospitals.

Besides his experimental work on abdominal war wounds, he is well known for having introduced tinct. iodine as a skin antiseptic and cocaine as a local anesthetic

school, and were supported chiefly by American and German protagonists. The abstentionists had their strongest adherents in France. Réclus (Fig. 323), one of the leading surgeons of the day conducted experiments, which he quoted in support of conservatism. For instance when a dog's intestine was wounded by a rifle or revolver bullet, protrusion of the mucous membrane produced such a "stopper" effect that in many instances it prevented the intestinal contents escaping. Again, even when a large perforation occurred, in many cases adhesions of the injured loop to an adjacent coil sealed the lesion and it ultimately healed. To reinforce his experimental conclusions, Réclus quoted a series of eighty-eight abdominal wounds treated on conservative principles. No less than sixty six of the patients recovered Incidentally we are not told the details of the visceral damage in this impressive series

With data such as this upon which to base their arguments, the school of abstentionists waxed and multiplied Their cause was further promoted by the reports which came in from three campaigns —the Sino Japanese the Spanish American and the Tirah expedition All were in the same vein laparotomy for war wounds had proved disastrous and had been either forbidden or discontinued by the respective Army medical departments

In the face of all this well founded opposition it may well be asked how the interventionists attempted to defend their views It will be recalled that this was the beginning of the Golden Age of the advance of abdominal surgery Laparotomy was becoming a recognized method of treating such conditions as perforated gastric ulcers, why, said the interventionists, should not success attend the comparable lesions of war? It was arguments such as these which must have influenced current thought just before the South African War of 1899 1901 At this time Colonel Stevenson, Professor of Military Surgery at Netley, urged intervention in cases of perforated wounds of the abdomen where there was reason to believe the intestine had been damaged, and his advice was followed in the early stages of the campaign. It was left to Sir William MacCormac (Fig 324), himself an erstwhile protagonist of intervention, to summarize the results In this (the South African) war,' he said, a man wounded in the abdomen dies if he is operated upon and remains alive if he is left in peace' Such was the pronouncement of one whose opinion carried much weight MacCormac's aphorism," as it came to be known, influenced treatment during the remainder of the South African War, and it became so instilled in British Army circles that it was still the order of the day in 1915

FIG 324

Sir William MacCormac (1836-1901)
After serving in the Franco-Prussian War of 1870 he moved from Belfast to London and became surgeon to St Thomas' Hospital From 1899 to 1900 he was Consulting Surgeon to the South African Field Force

The policy of non-intervention was also the official view during the Russo-Japanese War of 1904-5, and it would have remained so but for the drive and initiative of Princess Gedroitz, a Russian aristocrat who had received surgical teaching and qualifications in Germany She organized and equipped a railway carriage operating unit in such proximity to the battle front that it was possible to operate on penetrating abdominal wounds within a period of three or four hours of their being sustained Dramatic success attended her efforts Within a short time she convinced the Russian Army authorities that in dealing with perforating wounds of the abdomen time was the essential factor Moreover, if laparotomy was performed under reasonably satisfactory conditions within a period of three or four hours, results could be secured which were infinitely better than those afforded by a conservative policy

1915 AND AFTER

As has been mentioned at the opening of the 1914-18 war the policy enunciated in MacCormac's aphorism was followed by the British Army It is true that the character of the campaign and the limitation of transport made any method other than conservative treatment well-nigh impossible There is no doubt that during this, which may be termed *the first phase* of the Great War it was the precedent of the South African campaign rather than the lack of facilities which governed the treatment of abdominal war wounds The mortality was appalling In 1915 came *the second phase*—a period of dissatisfaction and of criticism It had become only too evident that high explosive shells produced lesions which failed to respond to conservative measures in anything like the proportion which had appertained in South Africa The change in the character of the missiles necessitated drastic revision in method of treatment There was a deepening appreciation of the value of early operation and an increasing demand for the provision of facilities which would give operation a reasonable chance of success

In *the third phase* the ideal was in a large measure achieved It was agreed that operation was the proper course to adopt and it was shown that in practice the matter was one largely of organization It became evident that we must strive to provide adequate facilities for treatment within the shortest possible time after wounding The difficulties in attaining that ideal may be many—there are instances in which they may well be insuperable —but none the less the ideal must be kept in view for the nearer we come to its fulfilment the lower will be the mortality

Present-day attitude—The necessity for early operation in cases of penetrating abdominal wounds with visceral damage is now accepted so generally that it is almost a routine measure but there are still occasions for exercising judgment as to when to perform operation and in a few cases whether to adopt conservative measures To-day as Sir Cuthbert Wallace has said it is really a question of excluding cases on which it is best not to operate It is true that the adoption of this principle involves operating on some patients who have no visceral injury and on others in whom the injury of solid viscera does not necessitate operation but making allowance for such possibilities it is the look and see policy that in the long run offers the greatest measure of security

Classifying cases—Accepting therefore the general principle of operating as a routine measure the surgeon will proceed to classify cases according to their state a necessary step in arriving at a decision regarding further procedure On this basis four possibilities present themselves —

(*a*) The patient s general condition is so good that operation can be undertaken without delay

(*b*) The existence of shock makes it imperative that time be spent in resuscitation before operation is embarked upon.

(*c*) The patient exhibits evidence of considerable internal hæmorrhage

(*d*) Late cases, in which the clinical picture is one of general peritonitis consequent upon the intestinal perforation

It is unlikely that differences of opinion will arise as to the appropriate method of dealing with cases belonging to the first two categories The third group presents a difficult problem—one which calls for that judgment and discrimination which experience alone can give Is the surgeon to operate immediately with the intention of arresting hæmorrhage and concentrate subsequently upon improving the patient's general condition by transfusion, or is he to adopt a conservative policy and attempt to improve the general condition before operating or should he adopt a compromise and operate while either a drip or more rapid transfusion is proceeding ?

Certain conclusions in regard to these critical cases were arrived at during the war of 1914-18 and again in the Spanish Civil War of 1936-38 and a summary of these impressions is as follows

Preparations for early operation should be made but while these are proceeding treatment for shock is instituted Transfusion is not carried out at this stage in case increased hæmorrhage is induced Within a short time the provision of warmth and the judicious use of body stimulants may improve the patient's condition, but, whether they have done so or not, operation is proceeded with and transfusion, preferably by the drip method, is given simultaneously and for such a subsequent period as may be necessary to replenish adequately the lost blood Experience has shown that this plan offers the best chances of success in the perforation-hæmorrhage type of case

In the fourth group, the late case in which diffuse peritonitis has supervened, it is best to adopt a conservative attitude, at any rate to commence with The Murphy-Ochsner principles are invoked By such measures as the application of warmth, the administration of continuous intravenous saline and the adoption of Fowler's position, an endeavour is made to help Nature to localize the infection before an operation is attempted

* * * * * * * *

The theme of this outline of evolution of abdominal surgery in warfare has been to show the necessity for early laparotomy Lest this be interpreted as rushing the patient to the operating theatre at the earliest possible moment, it may be well emphasized that such a practice is the antithesis of good judgment All patients with abdominal wounds will benefit from a period of preoperative preparation devoted to improving the physical condition it is difficult to conceive of any situation to which this recommendation does not apply Associated with every case of abdominal wounding there is a measure of shock, the features are exaggerated if there has been exposure to cold or undue delay in transport, and it is essential that steps should be taken to remedy the general condition before submitting the patient to the effects of what may prove to be a prolonged and difficult operation Experience has made it abundantly clear that a reasonable time devoted to resuscitation is time well spent

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CHAPTER XXXVIII

LAPAROTOMY FOR WAR WOUNDS

DIAGNOSIS—Difference of opinion sometimes arises as to whether a gunshot wound of the abdomen involves the peritoneal cavity or not Often this all important question can only be decided by laparotomy and it is better to look and see rather than to wait and see

The following points, taken collectively are important —

POSITION OF INJURY—It is first necessary to determine if possible the direction of the track The entrance and exit wounds give an idea of the path of the missile and the structures likely to be involved and may be a guide to the subsequent incision. Absence of an exit wound does not necessarily mean that the foreign body is lodged within the peritoneal cavity The possibility of its being buried in the parietes rectum or bladder must be excluded

PAIN is always present and varies to some extent with the degree of shock In profound shock the patient is more or less oblivious to pain Therefore the degree of pain is no indication of the severity of the intra abdominal lesion

TENDERNESS AND RIGIDITY are reliable signs although their absence is often misleading I have seen a flaccid abdominal wall in a case of multiple perforations of the bowel on the other hand board like rigidity is frequently met with in a parietal wound without peritoneal involvement If the interval between injury and examination is short tenderness may be localized to an area corresponding to the gut lesion but as infection disseminates so the tenderness becomes diffuse

The PULSE varies in rate it increases directly with the gravity of the intraperitoneal lesion and gives an important basis for prognosis

VOMITING is usually present Thirst is a most distressing symptom.

BLOOD PRESSURE and PULSE PRESSURE are useful guides as to the ability of the patient to withstand surgical intervention

X RAY LOCALIZATION should be undertaken when possible I always advise the radiologist to curtail his examination as far as possible even to the neglect of foreign bodies situated elsewhere in multiple wounding every effort should be made to keep the patient warm throughout the examination. In addition to demonstrating opaque foreign bodies radiography by revealing the presence of free gas in the peritoneal cavity may provide confirmatory evidence of intestinal perforation

On arrival at a casualty clearing station for the purpose of treatment patients should be classified according to their condition, irrespective of the class of wounds or site of injury —

(a) Those in good condition and operable
(b) Cases showing varying degrees of collapse from shock and internal haemorrhage.
(c) Late cases
(d) Cases in a dying condition, when nothing can be done except to relieve pain and thirst

Pre-operative treatment—Of cardinal importance is the treatment of shock Continuous intravenous saline plasma transfusion or drip blood transfusion is administered according to the needs of the patient, and can be continued with advantage during the operation Morphia is not withheld Rest and absolute quiet are essential

When to operate—The general condition of the patient must be watched carefully and the most suitable time chosen for the operation, which should not be undertaken before the patient has recovered from shock Two arguments have been put forward in favour of immediate operation —

1 That timely arrest of internal haemorrhage can be effected
2 That the earlier a breach of continuity of the alimentary canal is repaired, the less is the danger of spreading peritonitis

Against these arguments experience has proved that

1 By the time the patient has arrived at a casualty clearing station he is either moribund or suffering from extreme collapse, and consequently for the time being has ceased to bleed actively
2 No serious infection of the peritoneum from an intestinal wound takes place until the lapse of six hours from the time of the injury

It is therefore in the best interest of the patient to delay operation for a few hours, the aim being quick resuscitation before subjecting him to the further shock of an operation If the patient is in good condition and warm, then, of course, the operation can be performed without this delay

Anæsthesia—As a general rule, if a skilled anæsthetist is available, the anæsthetic of choice is gas and oxygen, with ether as required In my opinion spinal anæsthesia has little place in the surgery of abdominal injuries In selected cases local anæsthesia, either alone or combined with gas and oxygen, is of invaluable assistance, for it not only minimizes shock but aids in the relaxation of the abdominal wall

General principles in laparotomy—A prime consideration is the avoidance of further shock Speed, of course, is a great acquisition, but the keynote of success is gentleness Unnecessary exposure of the viscera must be avoided , the assistant should be instructed to make sure that all exposed intestine is kept covered with hot moist packs This raises a most important point The surgeon should be certain that there is a fool-proof organization for the counting of swabs and packs, for in a given case a considerable number of these may be used and the staff is likely to be harassed

PREPARATION OF THE SKIN—It is often advisable to delay the preparation of the skin until the patient is anæsthetized and the surgeon will employ the method of skin disinfection to which he is accustomed. The only variation between this and civil practice is that the entrance and exit wounds must be cleansed with meticulous care.

ARRANGEMENT OF INSTRUMENTS—*The number of instruments should be reduced to a minimum compatible with efficiency.* It is extremely important to have what may be termed a "dump" tray preferably near the patient's feet. Into this tray are cast soiled instruments. Another useful practice in these cases is to have as a routine what may be called a "closing" tray. This is equipped with artery forceps, scissors, catgut, silkworm gut, needles, needleholders, etc., all ready for immediate use. The object is to ensure closure of the parietes with the least possible danger of infecting them. With this aim in view the surgeon should change his gloves before closing the abdomen if the condition of the patient is not *desperate. The few moments expended in this manœuvre are well worth while.*

When should the entrance and exit wounds receive attention?— Unquestionably the best practice in most instances is to *defer attention to the entrance and exit wounds until laparotomy has been completed.* The sole exception is in the case of wounds of the back, buttock or posterior aspect of the thigh when it is important that these lesions should receive attention before the abdomen is opened. This prevents the necessity of turning the patient after the laparotomy, for experience has shown the step to be often detrimental.

Wound excision has replaced all attempts at local disinfection. It will be recalled that in the preliminary preparation the skin was shaved widely and the wounds cleansed with soap and water. In nearly all cases it is possible to excise the entire track of the missile right down to the peritoneum. Generally an elliptical skin incision is convenient. The skin is undermined and the edges retracted. The various layers of the abdominal wall are excised in one piece which encloses the whole length of the track. Throughout the procedure every effort is made to prevent carrying infection into healthy tissue. The objective is to remove the entire track of the missile from the skin to the peritoneum without permitting the knife or other instrument to touch the track or the infected surface wound. Should such an accident occur the soiled instrument or glove is discarded immediately. If the surgeon is satisfied that he has converted the contaminated wound into a clean one and that hæmostasis is complete the wound should be closed in layers without drainage. *There can be no definite ruling on when to drain.* So much depends on the nature of the wound and the length of time which has elapsed since the injury.

Late cases.—Most surgeons are agreed that small bowel perforations with evidence of diffuse peritonitis seen after about twenty-four hours are best treated on the well known Ochsner-Sherren principles with the additional application of gastric or duodenal aspiration. In favourable cases a localized collection of pus forms, in which event *the abscess is drained by the most appropriate route.*

There is no uncertainty as to the procedure in the case of large bowel wounds The large bowel, when injured, is not paralysed, and so there is continual leakage of its contents However late the case is seen, immediate operation is essential

THE STANDARD (MID-LINE) INCISION

With very few exceptions, which will be detailed presently, no doubt exists in my mind as to the best incision to employ It is the mid-line incision Its advantages are legion By employing it the abdomen can be opened quickly and, what is equally important, it can be closed rapidly It is comparatively bloodless and can be extended upwards or downwards according to the needs of the case

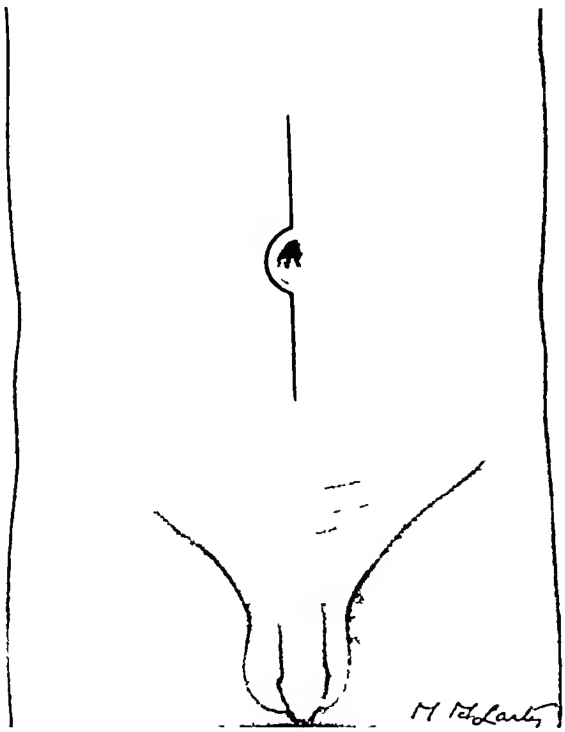

Fig 325
The standard incision for exploratory laparotomy for war wounds

The incision is commenced three inches above the umbilicus, curving one inch to the side and extending three inches below the umbilicus (Fig 325) Having completed the skin incision and having ligated bleeding points, towels are clipped to the skin edges It should be remembered that, except in the region of the umbilicus, the incision through the abdominal wall is exactly in the middle line When the linea alba is difficult to identify, a small transverse incision—little more than a nick—about two inches above the umbilicus will display the inner borders of the recti abdominis, and thenceforth no difficulty will be experienced in identifying the middle line Having completed the incision through the linea alba, the wound edges are lifted upwards and outwards with Lane's forceps and the peritoneum drops away from the fibrous aponeurosis The peritoneum is now lifted up and opened within the limits of the incision

Insertion of drainage tube—When intraperitoneal drainage is indicated, a small separate incision to accommodate the tube, *e g*, a suprapubic stab wound, may be preferable to accommodating the tube in any part of the laparotomy wound

Closing the abdomen—The peritoneum is picked up in hæmostats and closed by a continuous suture of chromic catgut If necessary, this is supplemented by an occasional interrupted suture (Fig 326) A series of stout silkworm gut sutures placed one inch apart are now inserted through all layers down to the peritoneum It saves time if these are threaded through suitable lengths of narrow rubber tubing as they are to act as tension sutures The aponeurosis on either side is closed by interrupted catgut sutures This is the most important layer of the abdominal wall and pains should be taken to ensure its firm closure The skin is then closed

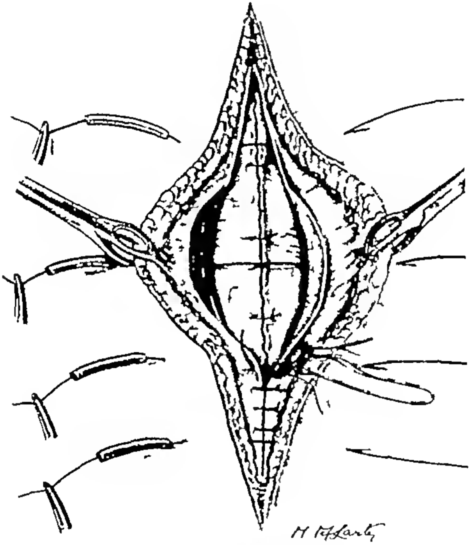

FIG 326

Closing the incision. The peritoneum has been closed by continuous suture reinforced by an interrupted stitch where necessary The aponeurosis is being approximated by interrupted sutures.

with interrupted sutures and finally the deep stitches are tied without tension. If it is considered advisable the subcutaneous tissues are drained by inserting a piece of corrugated rubber brought out at the inferior end of the incision

Having dealt with what justly may be termed the standard laparotomy incision for gunshot wounds we will consider other incisions which have a definite place in abdominal war injuries

THE TRANSVERSE EXTENSION OF THE MID-LINE INCISION

Wounds of the liver and spleen usually can be dealt with through the standard incision, but occasionally it is necessary to make a transverse extension outwards through all layers. This extension is repaired in the same way as the transverse incision described below.

THE TRANSVERSE INCISION

Towards the end of the last war I frequently used a transverse incision in the loin when dealing with wounds involving the colon. I regretted I had not employed the transverse incision earlier in the war, for its advantages

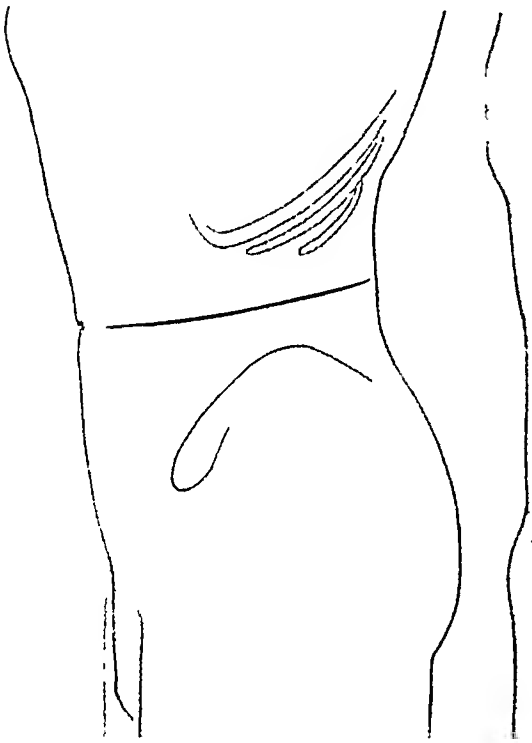

Fig. 327

The transverse incision

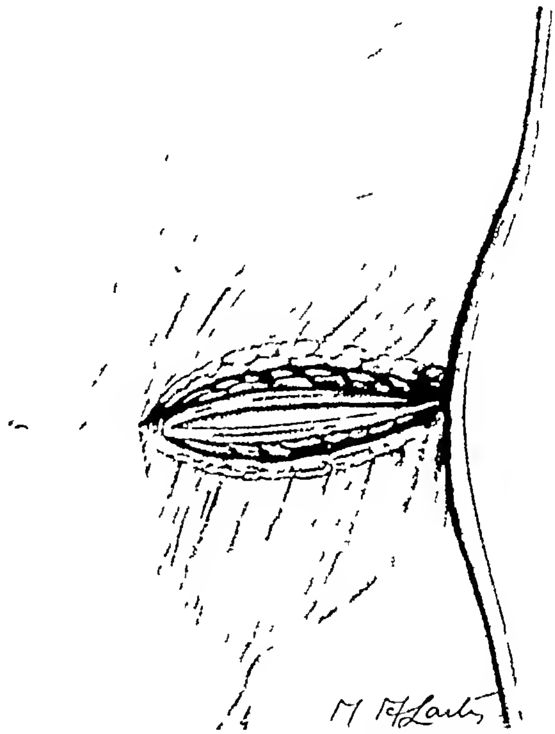

Fig. 328

All the lateral muscles are divided in the line of the skin incision, from the rectus abdominis to the erector spinæ

in colonic injuries are manifold. It affords direct access to the large intestine without unnecessarily soiling the peritoneum; it avoids to a large extent disturbing the small intestine; it affords access to a retroperitoneal colonic wound in a way which no other incision allows.

Position of the patient—By means of sandbags placed between the buttock and the spine, the patient is maintained in what may be termed "the one-third lateral position," *i.e.*, the abdomen as far as the umbilicus is readily accessible, as is also the loin as far as the outer border of the erector spinæ.

The incision is a long one (Fig. 327). It extends from the outer border of the erector spinæ and passes midway between the 12th rib and the iliac crest forwards to the outer border of the rectus.

All lateral abdominal muscles (Fig. 328) down to the peritoneum are divided in the line of the skin incision If necessary the incision can be extended posteriorly or anteriorly towards the mid line indeed if required the whole abdomen from the stomach to the rectum can be explored through this approach

Closing the abdomen—Often if this incision is employed in the correct type of case its closure must be modified For instance a temporary colostomy may have to be made in some part of the wound When a retroperitoneal wound of the colon is present the posterior portion of the transverse incision must be left widely open

The edges of the peritoneum are united The several layers of abdominal muscles are each picked up with hæmostats By taking this precaution it is easy to ensure that all layers of muscle are traversed by the interrupted No 2 catgut sutures which are used to approximate the muscular abdominal wall in bulk These sutures should be tied not too tightly The skin is closed by interrupted sutures Tension sutures are unnecessary for this type of incision

Wounds of the abdominal wall with loss of substance—In cases where large portions of the musculature of the abdominal wall particularly of the lateral abdominal wall (Fig 320) require excision the peritoneum is closed carefully and the cavity packed with vaseline gauze and over this the skin is partially sutured The gauze is not removed before it is felt certain that the parietal peritoneum is securely healed

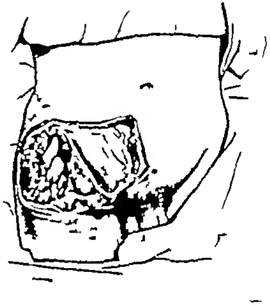

FIG 320

Shell wound of the abdominal wall.
(*British Journal of Surgery*)

When it is the rectus abdominis which is mainly involved and the gap to be closed is under 3 in wide direct suture is undertaken First of all a number of tension sutures of the stoutest salmon gut are passed through all layers of the abdominal wall not more than ¾ in apart While the sutures are passed the left hand is placed in the abdomen palm uppermost to guard its contents and guide the needle These sutures are left untied while the layers of the abdominal wound are approximated by stout interrupted catgut sutures which should be inserted from each end so that the tension in the middle is progressively decreased Finally the tension sutures are tied after rubber tubing has been slipped over them Adhesive strapping is used to reinforce the approximation

When the gap exceeds 3 in in breadth closure by direct suture is impossible and Ogilvie's operation should be employed

Light canvas or stout cotton cloth sterilized in vaseline is the best material A double sheet of this is cut rather smaller than the defect in the muscles, and it is sutured into place with interrupted catgut sutures. At one corner a small strip of vaseline gauze enters the abdomen as a drain (Fig. 330). This device is obviously temporary, but it prevents retraction of the muscular edges of the gap, and it keeps the intestines from protruding during the early days when they are so difficult to retain, and it allows the abdominal wall to be used as a whole in respiration. When the sutures come out, the edges of the defect and the surface of the viscera are covered by granulations, and the gap is less than would otherwise have occurred. The vaseline gauze, which must be thoroughly impregnated with vaseline and not merely smeared with it, makes an admirable peritoneum. The coils of gut move under it and it need not be removed for weeks, i.e. until the wound edges and their contents are fused in an oval of granulation tissue. On this surface pinch grafts are sprinkled liberally, and healing follows rapidly. Months later, the defect can be repaired by one of the accepted methods for dealing with ventral herniae.

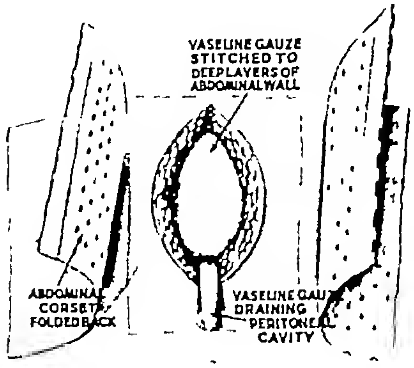

Fig. 330

A temporary peritoneum constructed of vaseline gauze for wounds of the abdominal wall with gross loss of substance

In cases of disruption of the wound, exactly the same principles are invoked, and where it is impossible to bring the edges of the wound together without enormous tension, the vaseline gauze method of making an artificial peritoneum should be employed.

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CHAPTER XXXIX

INTRA-ABDOMINAL PROCEDURES, INCLUDING WOUNDS OF THE SMALL INTESTINE AND MESENTERY

WOUNDS OF THE SMALL INTESTINE

WE will assume that the abdomen has been opened through the standard incision and that the exact nature of the intra-abdominal lesion or lesions is as yet undetermined The character of the peritoneal exudate will arrest attention Whichever viscus has been wounded a certain amount of blood will be sure to have been extravasated By mopping or suction this blood stained fluid is removed. If there is a considerable quantity of pure blood within the peritoneal cavity the primary concern is to locate the bleeding point and arrest hæmorrhage We will further assume that the bleeding is not progressive that the liver and spleen are intact and that there are no obvious indications of an intra peritoneal colonic wound In other words suspicion is directed to the small intestine and especially in cases where considerable hæmorrhage has been encountered to its mesentery

Because the transverse colon is so often implicated in gunshot injuries of the jejunum it is an excellent practice to commence the search by examining the transverse colon If a perforation of the large gut is encountered it must be closed immediately in order to lessen risk of peritoneal infection being disseminated from this dangerous field

Routine inspection of the small intestine—Beginning at the cæcum or at the duodeno jejunal flexure the small intestine is withdrawn and inspected carefully on both sides Each portion when its examination is complete is replaced within the abdomen for it is highly important to obviate the shock producing procedure of eventration If a small perforation is discovered the review is continued for a further 10 or 12 in and if no other damage is discovered the perforation is closed by suture and the examination continued The same procedure is adopted in respect of any other perforation which is discovered The importance of reviewing a sufficiency of intestine adjacent to any perforation is that it enables the surgeon to decide whether he should close individual perforations or resect a segment it is apparent that if there are several large wounds within a relatively short length of intestine (Fig 331) resection of this mutilated segment is often a wise course

If the first lesion discovered is large and if there is doubt whether it calls for suture or for resection it is well to delay a decision until the entire small intestine has been scrutinized While this essential but somewhat laborious measure is proceeding in order to prevent further escape of intestinal contents the damaged portion should be wrapped in a warm moist pack (Fig 332)

Suture or resection?—Experience has shown that suture of a perforation should be practised whenever possible Even when it entails a considerable narrowing of the intestinal lumen, suture is still indicated Extreme narrowing of the lumen of the gut—actually a rare sequel of suturing—is no argument against its performance Should this narrowing amount to occlusion it can be remedied by immediate lateral anastomosis between

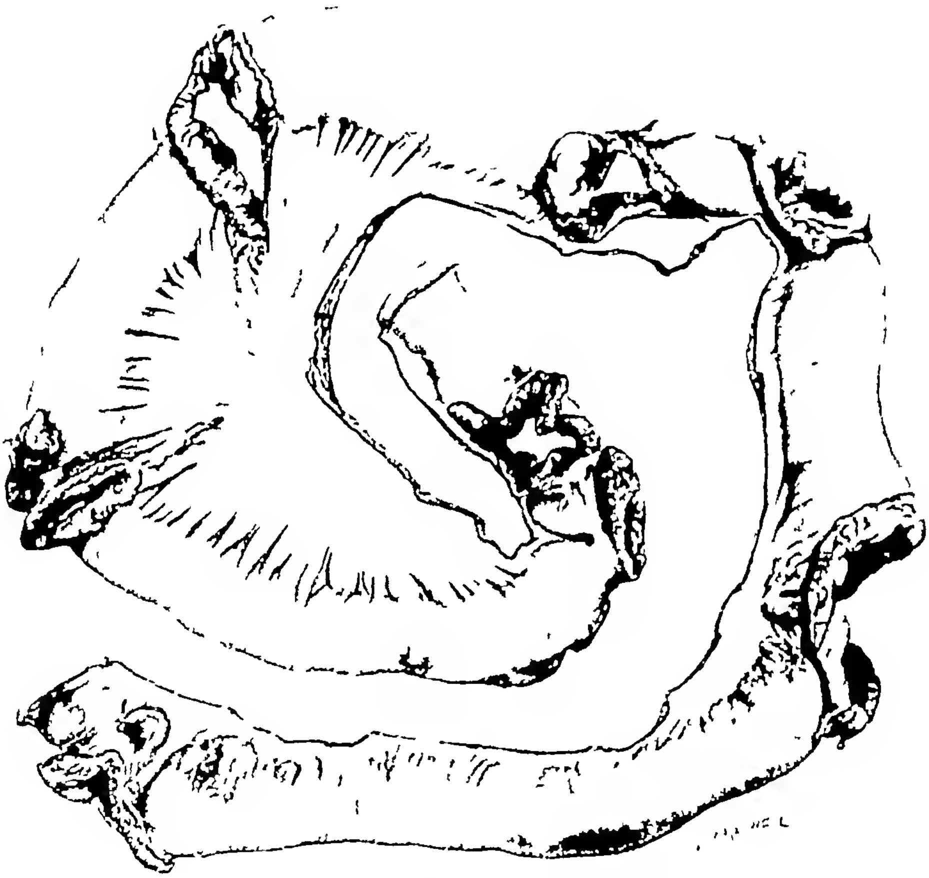

FIG 331

Multiple wounds of the small intestine produced by a single fragment
(*Hull's Surgery in War*, J & A Churchill Ltd)

the proximal and distal segments It is a well-established fact that the mortality associated with suture is considerably less than that of resection, and it is proper, therefore, that resection should be reserved for the conditions where there is no reasonable alternative, to wit

(*a*) Where a section of the intestine has been destroyed
(*b*) Where there are several large perforations within a short distance of one another
(*c*) Where injuries affecting the mesentery and its vessels endanger the vitality of the gut

In particular, multiple resections should be avoided, for the mortality following this procedure is particularly heavy

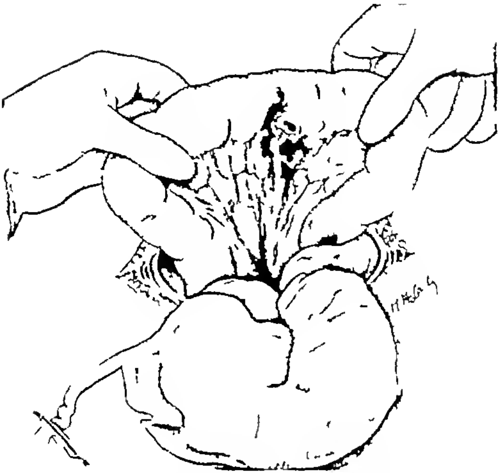

Fig 332
A wounded segment of small intestine should be wrapped in a warm moist pack while the remainder of the small intestine is examined

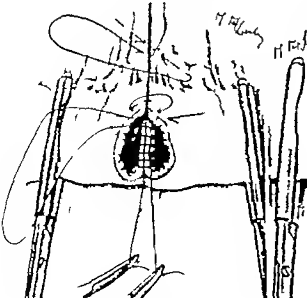

Fig 333
Connell suture

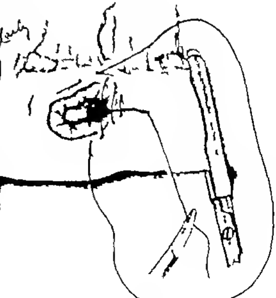

Fig 334
Cushing suture

Technique—Suturing the perforation—The section of small intestine containing the perforation should be controlled by a rubber-covered intestinal clamp If such a clamp is not available, a piece of narrow rubber tubing stretched between the beak and the handle of a long artery forceps serves the purpose (Fig 335)

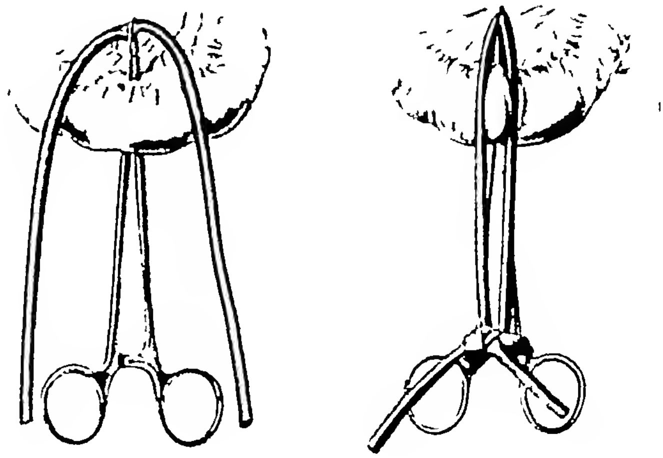

Fig 335
Method of improvising an intestinal clamp

When the edges of a perforation are ragged and bruised they should be excised, it is true that this increases local bleeding, but a healthy surface ensures sound healing

The suturing is carried out in two layers the first is a self-inverting stitch of the Connell (Fig 333) or Cushing pattern (Fig 334), the second is a Lembert stitch (Fig 336), and silk or linen thread or catgut may be used as the suturing material

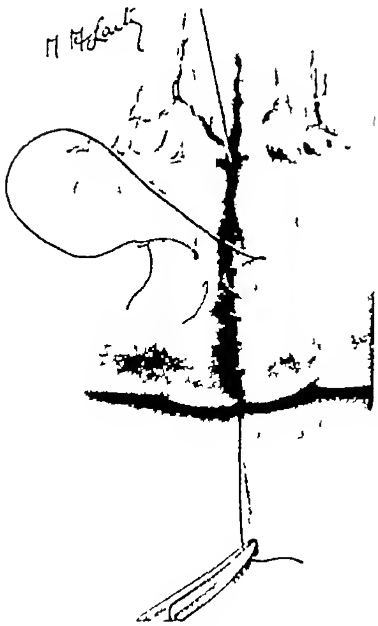

Fig 336
Lembert suture

There is a tendency to overstress the risks of narrowing the lumen of the bowel by suture the narrowing would have to be extreme before it constituted an obstruction to the liquid contents of small intestine By arranging that the closure is transverse to the long axis of the intestine undue narrowing is minimized

Resection—end-to-end or lateral anastomosis?—The choice between end-to-end or lateral anastomosis of small intestine is a matter of personal preference Certain statistical evidence is available regarding the risks of the respective techniques as exhibited under war conditions The analysis suggests that lateral anastomosis offers a 10 per cent greater degree of safety

A short circuit may be adopted when there is reason to anticipate obstruction from undue narrowing of the intestinal lumen following suture, or when damage to the mesentery may have jeopardized the peristaltic activity of a segment of the gut Short-circuit procedures implying the isolation of long segments of gut should be avoided, as they may result in serious nutritional disturbance

WOUNDS OF THE MESENTERY

Wounds of the mesentery are frequent complications of wounds of the small intestine it is uncommon to encounter them as independent lesions

Their significance is in relation to the amount of vascular damage which has arisen Injury to a large vessel in the mesentery results in a massive hæmorrhage and it may be the cutting-off of the blood supply to a considerable segment of the bowel wall

A pre-operative diagnosis of this injury cannot be expected It may be suspected when there are signs of severe internal hæmorrhage but it can be no more than a surmise the nature of the lesion becomes manifest only at laparotomy

Treatment—The primary duty is to arrest hæmorrhage and this the surgeon proceeds to do by hæmostats and ligatures but another and a more difficult matter has to be debated To what extent has the vascular

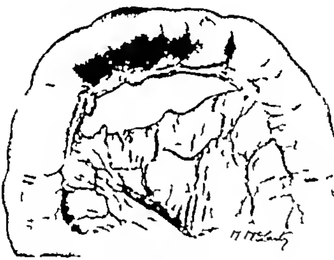

FIG 337

Type of wound of the mesentery which makes resection inevitable.

damage imperilled the viability of the intestine? Fortunately the collateral circulation in the mesentery is so copious that infarction is comparatively uncommon except in those instances in which large primary vessels have been damaged or when the mesentery has been wounded extensively In general it can be stated that the necessity for resection is less frequent than might be anticipated

For purposes of arriving at a clear understanding of when resection is necessary wounds of the mesentery can be divided into three varieties —

(a) *Wounds close to the intestino-mesenteric junction*—In this area long slit-like wounds may be encountered (Fig 337) The effect of such a wound is to cut off the bowel from its blood supply Undoubtedly these are the most dangerous wounds from the point of view of gut necrosis

(b) *Wounds of the mid-section of the mesentery* may be the source of considerable hæmorrhage, but, unless they are extensive, they rarely imperil the vitality of the intestine

(c) *Wounds close to the posterior attachment of the mesentery* are particularly liable to be concerned with severe hæmorrhage and with a vascular destruction which imperils a large section of the intestine

It may be said that, with the exception of the long slit-like wounds at the intestino-mesenteric attachment, the seriousness of mesenteric wounds increases the more centrally they are placed

Treatment will be adapted to the conditions which are encountered In a small wound bleeding is arrested by forceps and ligature, or by under-stitching, after which the wound is closed by suturing the peritoneum on the upper and under surfaces of the mesenteric leaf In larger wounds similar principles are followed, but, instead of picking up and ligaturing individual vessels, it may be preferable to insert a series of chain or interlocking ligatures parallel to the sides of the wound at a distance of about 1 cm from the edge The gap is afterwards closed by sutures which pick up the peritoneum only

It is difficult to lay down hard-and-fast rules regarding the indications for intestinal resection in mesenteric wounds The most constant indication is when the gut has been detached from its mesentery in excess of 2 in In wounds of a more central type attention should be paid to the appearance of the intestine in the segment under suspicion, evidences of œdema and cyanosis indicate serious interference with the circulation, and justify the decision to resect When there is real doubt and the suspicious area is limited in extent, it is well to temporize rather than to resect The doubtful loop can be ensheathed in omentum, as a safeguard against perforation, and the abdomen is closed Afterwards it is a matter of awaiting events and of being prepared to reopen the abdomen at once should the signs indicate that the vitality of the gut is failing The fruits of experience show that the risks entailed by this policy are not so much those of gangrene and perforation as an arrest of peristalsis and the development of intestinal obstruction An arrest of peristalsis and the development of intestinal obstruction can be forestalled by the comparatively simple expedient of lateral anastomosis So it comes about that lateral anastomosis, combined with omental ensheathment, have earned for themselves a very definite place in the treatment of mesenteric wounds which have jeopardized the blood supply to a limited portion of the intestine

INCIDENCE AND REGIONAL DISTRIBUTION OF WOUNDS OF THE SMALL INTESTINE AND ITS MESENTERY

In a series of 965 cases of wounds of the abdominal viscera collected by Sir Cuthbert Wallace, the number of small gut injuries was 363, in 255 of these the small intestine was the only hollow viscus wounded Damage to jejunum and ileum appear to occur with equal frequency, but the multiplicity of the coils of the latter predispose to a greater number of perforations of this segment of bowel in any single case Perforations of the thick walled jejunum are likely to remain circumscribed and in this area protrusion of the thick mucous membrane may offer considerable resistance to the escape of contents Wounds of the thin walled ileum are apt to be extensive and leakage is an early and a prominent feature in this area

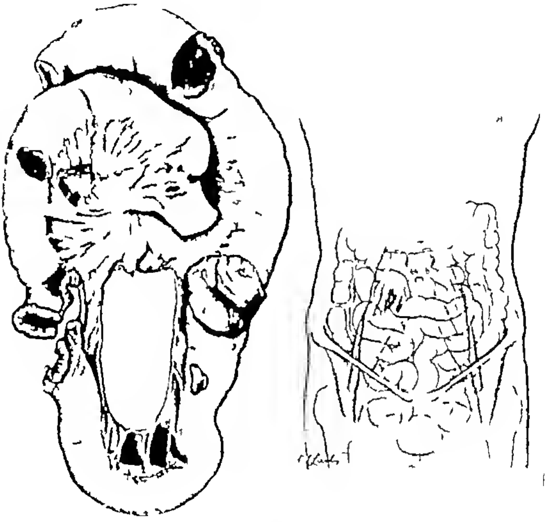

Fig 333

Portion of wounded small intestine showing extensive laceration of the mesentery Note the everted mucosa through one of the perforations.

The bullet track coursed 2 in. to the right of and below the umbilicus to the right psoas muscle The abdomen contained three pints of blood which was derived from the torn mesentery (W O Coll., R.C.S., 836.)

Wounds of the small intestine variation in infectivity—The infectivity of the bowel contents is another consideration which may be said to have a regional bearing The pathogenic flora of the small bowel are most numerous and active in the ileum *it is obvious therefore that a perforation* of this segment of gut is likely to be associated with an early development of peritonitis (*b*) *Wounds of the mid-section of the mesentery* may be the source of considerable hæmorrhage, but, unless they are extensive, they rarely imperil the vitality of the intestine

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Causes of death—Shock, hæmorrhage and peritonitis are the most frequent causes of death This is borne out by an analysis of seventy seven deaths reported by Sir Cuthbert Wallace in 1918 the results which he recorded may be summarized as follows —

CAUSES OF DEATH IN A CONSECUTIVE SERIES OF RESECTIONS AND SUTURES CARRIED OUT FOR UNCOMPLICATED WOUNDS OF THE SMALL INTESTINE

Total Cases.	Cause of Death	Number of Deaths.
77	Peritonitis	28
	Shock and hæmorrhage	26
	Gas gangrene of abdominal wall	9
	Mixed lesions	4
	Asthenia	2
	Paralytic ileus	2
	Pulmonary embolism	2
	Bronchitis	2
	Pneumonia	1
	Gangrene of lung	1

Mortality in relation to the time factor—There can be no doubt that mortality is intimately related to the time period to the length of the time which elapses between reception of the wound and the carrying out of surgical interference If the interval can be shortened there seems no reason why the death rate should not be reduced

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Mucous membrane eversion (Fig 338)—The eversion of the mucous membrane (a characteristic feature of jejunal wounds) has been the subject of study by McNee and Dunn, who contend that the eversion is due to the redundancy of the mucous membrane and to a retraction of the longitudinal coats These authors made a careful microscopical study of small intestine wounds They showed that the damage is remarkably local, the edges are so clean-cut that they might have been produced by a cutting instrument, while the further damage is restricted to a slight blood infiltration of the surrounding tissues

THE MORTALITY IN CASES OF WOUNDS OF THE SMALL INTESTINE AND/OR ITS MESENTERY

It is not disputed that spontaneous healing of small intestinal wounds can occur As has been shown in Chapter XXXVII, the possibility was so fully accepted in the South African war that it influenced the opinion of the medical service in the early days of the 1914-18 war in favour of conservative principles

Sir Anthony Bowlby and Captain Bell recorded a case of a soldier who sustained an abdominal wound at the Battle of Loos, and who, though not operated upon, recovered In the Battle of the Somme he was again shot in the abdomen, on this occasion laparotomy was performed, when several perforations of small intestine were found in loops of bowel matted together by adhesions, evidently the result of a former localized peritonitis The perforated and adherent segments were resected, and subsequent examination showed that an entero enterostomy had existed between adjacent loops and that, in addition, there were several small herniated diverticula of the mucous membrane indicating points of previous perforation These evidences were the result of the intestinal perforations sustained nearly a year before which had undergone spontaneous recovery This case is remarkable clinical proof of the experimental work recorded by Reclus in 1899 and repeated by Hamilton Drummond in 1916

It is evident that if a rigidly conservative attitude were adopted in cases of wounds of the small intestine, a certain number of patients would recover What the percentage would be it is not possible to estimate for there is no relevant data On the other hand, reliable statistics are forthcoming regarding mortality following wounds of the small intestine in patients submitted to laparotomy Again referring to Sir Cuthbert Wallace's series of 255 cases where the injury was restricted to the small intestine and its mesentery, the mortality was 65 9 per cent There is an impression that wounds of the jejunum carry a lower mortality than wounds of the ileum, but no accurate information is available on this point

Where perforation of the small bowel was accompanied by wounds of other hollow viscera the mortality figure varied from 70 to 100 per cent

Site of Wound	Total Cases	To Base	Died	Mortality
				Per Cent
Small gut and stomach	14	4	10	71 0
Small gut and colon	85	22	63	74 0
Small gut and rectum	4		4	100 0
Small gut, stomach and colon	5		5	100 0
Small gut and bladder	16	1	15	93 7

It is evident from this table that when wounds of the small intestine are complicated by wounds of the bladder and rectum the prognosis is particularly grave they may be associated with damage to the lower end of the œsophagus they are often complicated by involvement of the lower part of the left chest and their exposure presents many practical difficulties A large percentage of stomach wounds are associated with damage to other viscera —in the series quoted by Wallace 33 per cent were thus complicated

Two other features call for comment Hæmorrhage is usually considerable and as might be anticipated wounds involving the curvatures of the stomach are especially liable to be accompanied with severe bleeding The other comment concerns the development of peritonitis Infection develops but it is often delayed over a longer period than might be expected probably for the reason that the presence of a large amount of blood in the peritoneal cavity inhibits early activity of bacteria

Clinical features—Vomiting is a most constant feature in stomach wounds It is not a copious vomit though a quantity of blood may be ejected it is rather a persistent retching and it is probable that this is caused by irritation of the vagus nerve In addition to the vomiting there is pain often intense and the usual syndrome associated with perforation of a hollow viscus Sometimes stomach contents gas and bile may be seen escaping from the surface wound.

Treatment—As in perforated gastric and duodenal ulcers the earlier the operation the better the prognosis In the stomach perforations of war there is the additional urgency incurred by severe and progressive hæmorrhage

OPERATIVE PROCEDURE—It is important to examine both walls of the stomach access being gained to the posterior wall by opening the anterior layers of the great omentum a short distance below the greater curvature of the stomach

Local suture is always preferable to anastomosing or resection operations Even such an extensive injury as complete division of the stomach can be repaired effectively by careful apposition of sutures

It is possible that conditions will be encountered in which destruction of the pyloro-duodenal junction make it imperative to carry out an operation of the gastro jejunostomy type Such occurrences are of the utmost rarity

There is no question that repair of stomach wounds by suture meets all ordinary demands If the wound edges are ragged and contused they are excised Bleeding is arrested and approximation is secured by catgut sutures inserted by the Connell or Cushing technique so as to secure efficient hæmostasis and at the same time inversion of the mucous membrane edges An overlying stitch of fine silk or linen thread applied in the Lembert manner completes the closure

Wounds of the cardiac end of the stomach, particularly those involving the lesser curvature in proximity to the œsophageal opening present a special problem on account of the difficulty of access If the wound involves the lower chest in addition to the stomach the transpleural route may be employed. In this event the sixth rib is mobilized by division of its costal cartilage and the chest is entered through the anterior half of the space between the sixth and seventh ribs This brings into view the upper surface of the diaphragm, and by enlarging the wound which is present or by primary division of its fibres the cardio-œsophageal junction of the stomach is

CHAPTER XL

WOUNDS OF THE STOMACH, DUODENUM, LIVER AND SPLEEN

WOUNDS OF THE STOMACH

INCIDENCE—In a series of 965 wounds of the abdomen Sir Cuthbert Wallace encountered 82 examples where the stomach was involved, an incidence of 8 5 per cent In 55 instances the stomach was the only hollow viscus damaged

Surface wounds—Penetration of the left upper abdominal quadrant, high side-to-side wounds and left low chest wounds are those most apt to be associated with damage to the stomach wall

Fig 339

Bullet wound of the stomach The missile struck the distended organ obliquely, producing this large wound (*Hull's Surgery in War, J & A Churchill Ltd*)

Morbid anatomy—There is great variety in the type of wound which may be displayed (Fig 339) Perforation of both walls may be encountered, at other times the greater or the lesser curvature suffers damage Complete division of the stomach wall has been noted on several occasions From the surgical standpoint wounds of the cardiac end offer peculiar problems, they may be associated with damage to the lower end of the œsophagus they are often complicated by involvement of the lower part of the left chest and their exposure presents many practical difficulties A large percentage of stomach wounds are associated with damage to other viscera —in the series quoted by Wallace 33 per cent were thus complicated.

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Mortality—When the wound is confined to the stomach the post-operative mortality is about 50 per cent. The prognosis is more serious if there is an associated wound of the liver, but much more so if the spleen is wounded. A combination of wounds of the stomach, small intestine and colon has up to the present been invariably fatal.

WOUNDS OF THE DUODENUM

A penetrating wound restricted to the duodenum is extremely rare; rupture, the result of indirect violence is more often encountered. When one takes into account the anatomical relations of the viscus it becomes obvious that a perforating wound is almost certain to be associated with injury to one or other of the neighbouring viscera. The incidence of duodenal wounds was reported by Wallace as sixteen examples in 363 small gut injuries.

Treatment—Duodenal wounds are apt to be extensive. The thin muscular wall rips and tears over a wide area so that there is a considerable and persistent escape of contents. Closure may present many difficulties, particularly when the second part of the duodenum is involved—for here the opening of the common bile duct must be preserved. If suture is possible it is the method of choice. If closure results in undue narrowing of the duodenal lumen a gastro-jejunostomy will be required. In certain instances it may be necessary to divide the stomach through the pyloric antrum, closing the distal end and uniting the proximal opening to the jejunum as in a Polya partial gastrectomy. By this means a degree of duodenal closure can be effected which would otherwise be impossible.

Mortality—The immediate mortality of duodenal wounds must be very high. We have no knowledge of the exact figures, but it is evident that there is a heavy death rate within the first hour or two from hæmorrhage and from shock. The post operative mortality is estimated at about 80 per cent.

WOUNDS OF THE LIVER

Wounds of the liver present a variety of problems. Some are connected with diagnosis, some with such technical matters as the arrest of hæmorrhage, while others concern the difficulty of deciding between conservative and operative treatment. In answering these difficult questions experience is a great asset.

Frequency—What of the frequency of these injuries? They are relatively common. In Wallace's series the incidence in abdominal wounds generally was 16.8 per cent., but this is probably an underestimation, as it was confined to cases observed at operation. As will be seen presently, there must have been many cases where operation was not performed.

Morbid anatomy—Projectile wounds of the liver are usually commensurate with the shape and size of the missile (Fig. 340), but sometimes the damage is out of all proportion; for instance, a bullet track through the organ may be associated with extensive fissuring radiating from the primary wound, or the whole liver may be shattered.

The dynamics of these various lesions have never been explained fully no doubt the friable nature of liver substance predisposes it to fissuring, but there must be other factors the nature of which is obscure

The surface of a recent liver wound is ragged and blood stained Within twenty four hours it takes on a dirty yellow appearance the result of local necrosis Later when bile-staining occurs it assumes a vivid yellow hue

Multiple infarction is a common sequel, and as a result areas of focal necrosis are encountered at varying distances from the original wound. Hæmorrhage is usually profuse and if the wound passes deeply into the

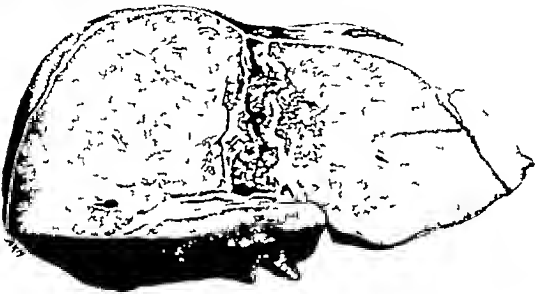

FIG 310

Gunshot wound of the liver showing a long tunnelled track. (*British Journal of Surgery*)

liver substance bile is excreted, commencing about twelve hours after the injury Wounds of the gall bladder the cystic and common ducts may occur in association with lesions of the liver substance

Associated wounds of other organs—It is a fortunate circumstance that only a small percentage of liver wounds are complicated by injury to other abdominal viscera in Wallace s series of 163 liver wounds only 15 were so associated (9 2 per cent) A combination of liver and right lower chest wounds occurs in an appreciable proportion of cases no accurate figure of the incidence is available but a study of the anatomical relation ship will demonstrate the likelihood of its occurrence

Clinical features—The clinical features depend upon the extent of the liver damage

In a small and superficial wound the resulting disturbance may be extra ordinarily slight The picture is one of physical distress rather than of shock. There is pain over the right hypochondrium and posteriorly below the angle of the right scapula breathing is accelerated, and often has a characteristic catch on inspiration. On the other hand, many liver wounds are associated with profound shock out of all proportion to structural damage and loss of blood.

Hæmorrhage is generally profuse venous in origin, if a large vein is damaged, it quickly assumes dangerous proportions. Otherwise it tends to cease spontaneously in from six to twelve hours.

Jaundice of a slight and evanescent character may be noted a few days after the wound has been sustained; apparently it is toxic in nature.

Bile from a liver wound may escape into the peritoneal cavity in sufficient quantity to cause a biliary peritonitis. Such peritonitis is associated with paralytic distension and the complication is a peculiarly fatal one.

Apart from these specific features there are the usual signs associated with injury of the abdominal viscera.

Physical examination—The omission of an examination of the chest may result in the overlooking of a hæmothorax, a lower lobe collapse, or a commencing pneumonia. When there is a wound of entrance only, an X-ray examination affords valuable information.

Diagnosis and treatment—If one can satisfy oneself that the wound is restricted to the liver it is probable that an expectant treatment is the best course.

The patient is nursed in a sitting-up position. Measures are taken to counteract the shock; pain is relieved by the administration of morphia, and after six hours, when spontaneous arrest of bleeding may be expected, an infusion of blood or plasma is given if the general condition demands it. By adopting a scheme of this kind it is probable that reasonably good results would be obtained, but it entails accuracy in diagnosis to a degree which is rarely attainable. So often the fear that the liver lesion is associated with a perforation of a hollow viscus leads to a decision to explore the abdomen.

Are there any means by which the diagnosis can be made more certain? Possibly there are. A careful study of the position of entrance and exit wounds may result in accurate orientation of the missile's track. In the case of a single wound of entrance the accurate X-ray localization of the missile is likely to afford similar information. Repeated examination of the abdomen, combined with a careful record of the pulse, may eliminate the existence of a perforation of a hollow viscus. By a combination of these observations it should be possible for the surgeon to become confident that the damage is restricted to the liver. Nevertheless, in many instances—and they are the majority—doubt exists and the only means by which the doubt can be set at rest is by laparotomy.

Operation—When the missile has entered through the thorax the transpleural route is preferable. In other circumstances, the area is explored through an oblique subcostal or a right upper paramedian incision.

If the liver wound is small and bleeding has ceased, it should be left undisturbed. Large wounds and those which continue to bleed are packed with gauze which has been soaked in 1 : 1,000 acriflavine. Obvious bleeding from a vessel is arrested by undersewing it with catgut on a small round-bodied fully curved needle.

Should an attempt be made to suture liver wounds? In theory a positive advice is given, but in practice there are real difficulties. Every needle puncture starts a fresh hæmorrhage, stitches cut out, and the friable liver substance breaks away; too often the latter state is worse than the first, and bleeding is augmented instead of reduced. Except for superficial wounds and those involving the free edge of the liver it is doubtful if suture should be practised Packing is infinitely better and when the time comes for its removal if it is extracted gently and gradually no undue hæmorrhage occurs.

Wounds of the gall bladder and bile ducts are dealt with on the ordinary lines by either suture drainage or in the case of a severely damaged gall bladder by removal of the organ.

Mortality and causes of death—The pre-operative mortality of uncomplicated liver wounds treated conservatively is estimated at about 30 per cent This may seem an unduly high figure but it must be remembered that in a proportion of cases the destruction of liver tissue is very great There are no reliable figures of *liver wounds per se treated* by *operation* to enable us to draw a comparison. The causes of death may be grouped as early and late of the early causes there are really but two shock and hæmorrhage The late causes are more numerous—they are secondary hæmorrhage sepsis biliary peritonitis and pneumonia

WOUNDS OF THE SPLEEN

Wounds of the spleen form an important section of the abdominal injuries of warfare They are associated with a high mortality but at the same time if recognized sufficiently early and treated appropriately they yield most encouraging results

Frequency—Their incidence has been estimated at about 5 6 per cent

Association with other injuries—The situation and relatively small size of the organ seems to imply that an uncomplicated wound must be rare but in fact such is not the case In a series of 54 wounds involving the spleen 32 were pure splenic wounds (Wallace) When other organs are damaged it is the stomach the left kidney the splenic flexure of the colon and the jejunum which figure in the list.

Clinical features—Hæmorrhage mainly internal is the leading feature of a wound of the spleen Clinically two types are encountered. In the first the hæmorrhage has been so severe that when the patient comes under observation he is in a collapsed and often unconscious state In such cases the splenic pedicle has been damaged large vessels have been severed and the abdominal cavity is flooded with blood In the second group the picture is different Following the wound there has been an appreciable immediate *hæmorrhage shock then develops and with the fall of blood* pressure bleeding is arrested for the time being A latent period follows while recovery from shock is taking place the blood pressure is rising and the general condition of the patient is improving It is at this stage that a further hæmorrhage occurs. It is a true reactionary hæmorrhage and with its appearance there is a further decline in the patient s condition. This sequence of events is indicative of a wound of the spleen substance

Treatment—Operation should be undertaken without delay If the signs of hæmorrhage are marked, a blood transfusion should be given coincident with the operation.

OPERATION—If the diagnosis is tolerably certain a left paramedian incision affords good access to the spleen while it also permits adequate exploration of neighbouring viscera

As in the case of traumatic rupture so it is with wounds of the spleen In the great majority of cases splenectomy is the proper course to adopt (Fig 341)

If it is found that the paramedian incision affords insufficient access and bleeding makes rapid action imperative, the left rectus muscle is cut transversely at the junction of its upper and middle thirds The injured organ is brought to the surface and bleeding is arrested by grasping the pedicle between the fingers or in a rubber-protected intestinal clamp A further review of the damage is now made Very occasionally suture may be possible As a rule preparations are made to complete the splenectomy. After division and ligature of the gastrosplenic omentum the spleen is drawn downwards and towards the middle line The posterior leaf of the lieno-renal ligament is divided. and the vascular pedicle is exposed The pedicle is double ligatured and divided and the spleen excised Clots and free blood are removed and the neighbouring viscera are inspected for possible damage, particularly the stomach the left kidney, the duodeno-jejunal flexure and the upper coils of the jejunum The abdominal wound is closed, and arrangements are made to continue the blood transfusion until such time as the patient's condition is improved

FIG 341

Spleen (Richard Charles' case)

The passage of the small piece of shrapnel shown was responsible for the extensive injury, the upper fragment having been entirely severed. Specimen obtained at operation a few hours after injury

(*British Journal of Surgery*)

Chest wounds as a complication—If a wounded spleen is accompanied by an injury to the lower chest it is *not* advisable to attempt to deal with the spleen by the transpleural route. The abdominal route should always be employed as a primary measure the thoracic wound being dealt with from the chest side

Mortality and causes of death—The mortality in uncomplicated cases has been estimated at 40 per cent This figure is much higher than that encountered under civil conditions, for the reason that the exigencies of war create situations which are not favourable to early treatment Hæmorrhage is the main cause of death

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CHAPTER XLI

WOUNDS OF THE LARGE INTESTINE

ANATOMICAL disposition preserves the large bowel from those multiple wounds which characterize injuries of the small intestine perforating wounds of the jejuno ileum frequently complicates large intestine lesions and many and diverse are the associated injuries that menace the life of the wounded man apart from his damaged colon

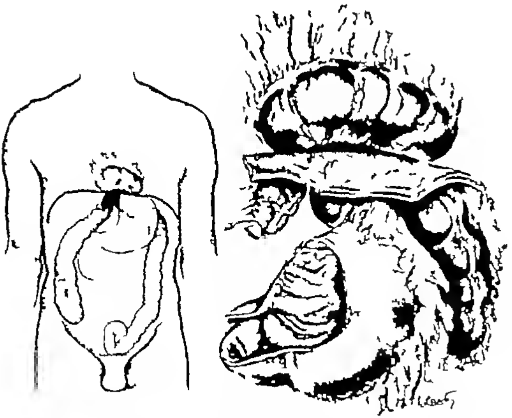


FIG 342

Diaphragmatic hernia—The transverse colon projects as a hernia through a gun-shot perforation in the diaphragm. The opening is oval, measuring $1\frac{1}{4} \times 1$ in. There are no adhesions around the orifice and the whole mass now above the diaphragm could readily be reduced (W O. Coll., R C.S., 1163.)

Even when the colon is the only viscus involved the mortality is high when the lesion is complicated by wounds of other intraperitoneal organs the already high mortality rises precipitately (see p 414)

Subparietal rupture of the large intestine without breach of skin is a clinical entity which has become recognized in maritime warfare It is due to the detonation of a depth charge while the shipwrecked victim is in the water Some of these cases have been dealt with successfully by primary operation, in others a contused colon has permitted the permeation of organisms, and a subsequent abscess and even a fæcal fistula have resulted Still others injured by this form of violence have suffered from severe meteorism associated with an increase of temperature and pulse rate which occasioned anxiety, but have fortunately recovered without more serious incident in such the diagnosis between contusion of the colon and some retroperitoneal injury or hæmatoma must remain in doubt

Fig 343

Gunshot wound of cæcum viewed from behind There is extensive hæmorrhagic infiltration of the bowel wall Fragment of high explosive lodged in bowel wall (W O Coll, R C S, 921) *(From the author's "Abdominal Injuries of Warfare" John Wright & Sons Ltd)*

Traumatic lesions of the large bowel are very lethal—Life is not only threatened by a penetrating wound of the colon, the unwounded splenic flexure has been strangled in the diaphragmatic rent produced by an abdomino-thoracic injury (Fig 342)

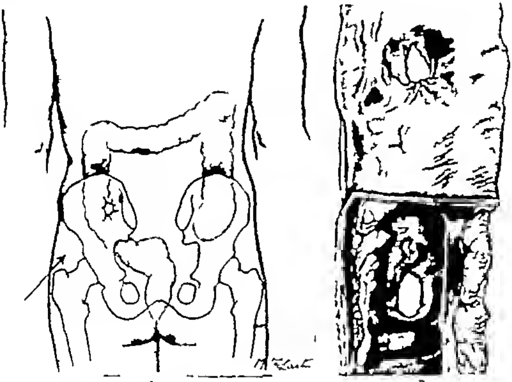
Recent experiences in no way refute the grave view of wounds of the large bowel that was entertained twenty years ago In respect of the more frequent and typical gunshot wounds of the colon, anatomical considerations play no small part in determining their serious character

(*a*) In the present war the tendency for wounds of this portion of the bowel to be retroperitoneal is even more in evidence Yet their liability to be overlooked by the surgeon has not decreased

(*b*) The vulnerability of the retroperitoneal tissues to infection, more especially to anaerobic invasion, adds to the gravity of gunshot wounds of the large bowel, the absence of a mesocolon in certain segments of the large gut, whereby the bowel and the lethal retrocolic and paracolic tissues are more closely approximated, increases the potentialities of these vertical portions of the colon for threatening life in the event of wounding

(*c*) Concomitant bruising of the large bowel is often considerable, and sometimes extends no small distance from the margin of the actual wound (Fig 343), this phenomenon is encountered more frequently than in corresponding wounds of the small intestine, surgical suture of the colon is thus rendered less certain and secure A deposit of fat in the wall of the colon tends to mask this bruising and demands watchfulness on the part of the surgeon The presence of extravasated blood in the intestinal coats of the obese should engender a sense of insecurity and calls for prophylactic measures against possible subsequent perforation

Isolated bruised areas are often seen on the large bowel and are not infrequently remote from the track of the missile such contusions vary in depth and surface extent and occasion concern in view of their liability to lead to secondary perforation (Fig 344 A and B) Prophylaxis



A B

FIG. 344

A *Post mortem findings*—There was a wound of the left buttock above the great trochanter from which the missile passed inwards and backwards, perforating the left iliac bone at the posterior edge of which it was impacted. The peritoneum was uninjured. The abdomen contained half a pint of fæcal fluid. There was bruising of the descending colon just above the iliac crest; in the centre of this area was a perforation. B, the mucous membrane had been separated from the muscular coat over a considerable area. (W O Coll., R C S., 927)

against this sequela demands the most careful provision for adequate drainage

(*d*) The outer coats of the large gut are sometimes ruptured and stripped back from the underlying intact mucosa this phenomenon is sometimes discovered in close proximity to the track of the missile and at other times may be remote from the actual perforation of the bowel These injuries add to the anxieties of conservative surgery (Fig 34)

(*e*) The more fixed portions of the colon contrast with the small intestine in the matter of surgical accessibility and the exposure of a retroperitoneal wound of the flexures or of the vertical segments of the colon through a mid line incision may be associated with serious technical difficulties (*f*) The early escape of fluid fæcal material from the lumen of the large bowel in cases of gunshot injury seems more frequent than from the small gut, and its occurrence augments the gravity of the prognosis, a peritoneum inundated with a flood of highly infective fluid from the intestine, the extraperitoneal tissues or a psoas muscle soaked and sodden

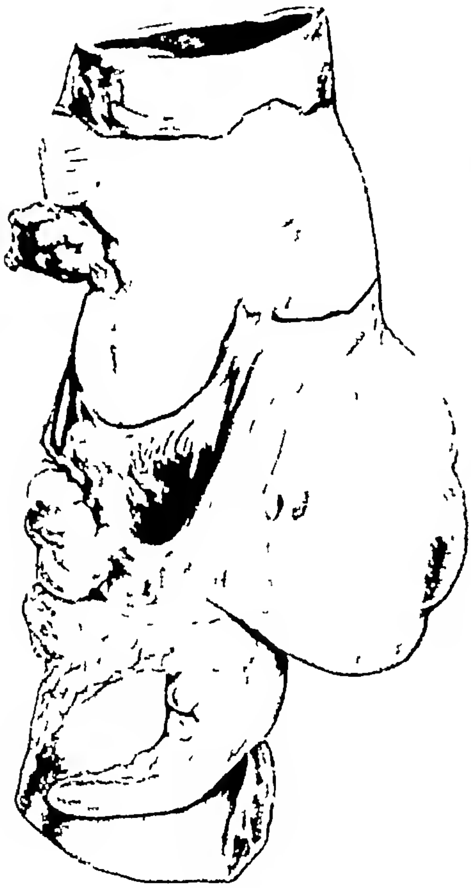


FIG 345

Gunshot wound of the ileo cæcal junction, the wall of the caput cæci is tense with blood extravasation There is an incomplete rupture of the wall of the cæcocolic junction produced by indirect violence (W O Coll, R C S, 920)

FIG 346

Gunshot wound of splenic flexure of colon viewed from behind Large ragged anterior and posterior perforating wounds, with infarction (W O Coll, R C S, 906*a*) (*Figs 163 and 164 from the author's 'Abdominal Injuries of Warfare' J Wright & Sons Ltd*)

with escaping contents render efforts to save the patient fruitless and wasteful of time

(*g*) Infarction (Fig 346) is more frequently met with in the large bowel than in the small intestine in cases of gunshot wounds such cases demand drastic rather than conservative measures

SITES OF INJURY

There is no unvarying uniformity about the disposition of the hollow abdominal viscera, and on the left side of the peritoneal cavity the descending and iliac portions of the colon are frequently overlapped by coils of small gut Furthermore in only about 60 per cent of the cases of large intestine injury is the colon the only segment of the alimentary canal involved in 40 per cent of the cases large intestine injury is complicated by other lesions

GUIDING PRINCIPLES IN THE TREATMENT OF WOUNDS OF THE COLON

1 In most cases the surgeon will be wise who at least primarily employs the standard mid line incision (p 380)

2 If preliminary laparotomy reveals no intraperitoneal injury great care must be taken not to convert a small or uncomplicated extraperitoneal wound of the cæcum or the vertical colon into one which compromises the general peritoneal cavity Such smaller wounds of the bowel may be trimmed and sutured from a posterior approach provision being made through the muscle-cutting flank incision for drainage of the contaminated area

3 Should the position of a colon wound revealed by laparotomy render the injury inaccessible to surgical suture or other treatment through a mid line incision or should additional provision for drainage appear desirable or imperative approach can be made by a supplementary incision in the flank or at the periphery of the abdominal wall If there chances to be a wound of entry or of exit in flank or iliac fossa or over some remote corner of the abdominal cavity this may be excised enlarged and converted into a more convenient avenue of surgical approach to the injured abdominal area

4 In civil surgery the writer has a predilection for incisions made directly over the portion of the colon which demands resection or other surgical treatment A flank iliac or even a subcostal incision in which the muscles are divided in order to ensure adequate exposure of the field of operation reduces to a minimum the anxieties of handling wayward small intestine and the dangers of generalized contamination of the peritoneal cavity are thereby reduced

Such incisions have a place in the surgery of warfare especially on the right side of the belly In the case of through and through wounds of gunshot origin far out in the flank or iliac region where any injury to the abdominal contents seems problematic or where the outer border or posterior surface of the colon is the most likely site of visceral injury the transverse incision (p 400) may be utilized profitably

The surgical treatment of the colon wound will vary with the anatomical and pathological character of each individual injury the measures adopted may also be dictated by other considerations such as the coexistence of multiple injuries in other parts of the body severity of concomitant hæmorrhage etc

1 Intraperitoneal Wounds of the Colon of Less Severe Type such as intraperitoneal tears perforations or incomplete division of the gut (Fig 347) merely require the trimming of damaged edges and suture yet in the case of wounds of this part of the bowel there is not the selfsame reliance in the efficacy of a single suture line that obtains in small intestine injury and most surgeons will employ a double-decker Confidence will be increased if a graft of omentum or an appendix epiploica can be utilized

to reinforce the suture line. This is the type of colon injury which promises the greatest hope of a successful result.

2. THE MORE FREQUENT AND TYPICAL INJURY OF THE COLON has unfortunately many of the features which have already been enumerated as balefully influencing the prognosis in large intestine lesions. Most of the wounds are associated with greater contusion than obtains in the small bowel; infarction is more frequent, and the adjacent extraperitoneal tissues of the postero-lateral wall of the abdomen are often the seat of a hæmatoma, certainly contaminated, perhaps already gravely infected with organisms which may have been introduced with the missile, or may have been denizens

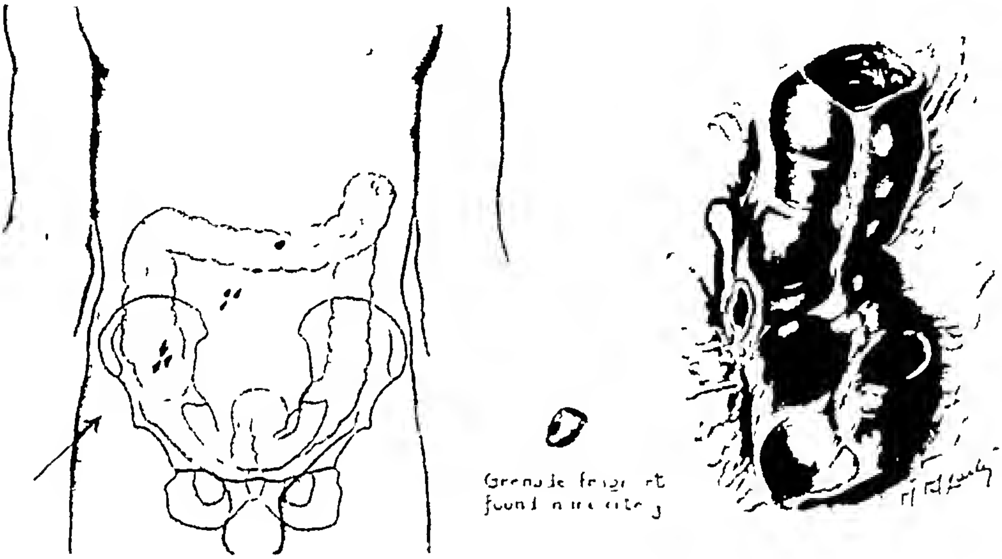


FIG. 317.

Transverse colon doubly perforated by a grenade fragment. One opening is of oval form ¾ × ½ in. with clean cut edges. The other, adjacent to the attached omentum, is smaller and less regular in outline. The patient was wounded by a grenade and died in the Casualty Clearing Station from shock twelve hours after operation. In addition to the double perforation of the transverse colon there were three holes in the ileum and three in the mesentery, in one of the latter the piece of metal was found lodged. (W. O. Coll., R.C.S., 904a and 904b.)

of the lumen of the injured intestine. In some cases the wounds are large and gaping; they are rarely multiple, but the damage and tearing of the coats of the cæcum or colon may render local suture unpromising. Emphasis cannot be laid too strongly upon the extreme probability that a wound of the colon is of a perforating character, and it behoves the surgeon to assure himself as to the existence or absence of a retroperitoneal wound in addition to more obvious and accessible intraperitoneal injury of the large bowel. Retroperitoneal colonic injuries with consequent infection of the connective tissue planes and muscles of the postero-lateral abdominal wall are much more fatal than intraperitoneal wounds. This type of lesion, especially of the more fixed portion of the large intestine where no mesentery is present, is sometimes associated with a train of symptoms indicative of an intense and rapid septicæmia, to which Sir John Fraser applied the term "colon septicæmia."

The writer has sometimes been credited with the advocacy of resection as opposed to suture in cases of gunshot wounds of the colon This is far removed from the truth There can be no doubt about the place of *suture* in most *intraperitoneal colon wounds* and also about the indication for suture in conjunction with efficient drainage of the neighbouring area in many extraperitoneal wounds where this technique offers a reasonable prospect of success *suture and drainage* may even be combined with *colostomy* in cases where grave infection is feared As a means of preventing fatal infection of the retroperitoneal space colostomy sometimes proved valuable in the last war but this operation must be performed at a very early period before infection actually obtains hold of the vulnerable tissues behind the peritoneum

It is by no means remarkable that resection should have been discouraged in the war of 1914-18 in the case of gunshot wounds of the large bowel for the approximation of healthy segments of colon after the removal of damaged gut is in most parts of the large intestine a far less simple surgical exercise than in the case of the closely approximated coils of jejuno ileum with their common mesentery The sacrifice of considerable segments of sessile colon may be necessary in order to secure a satisfactory end to-end union of undamaged segments of large bowel without tension

Nevertheless there are colon injuries in which *resection* alone seems to offer a hope of recovery Such cases include those where —

(a) The cæcum or colon is in a condition of infarction.
(b) There is extensive separation of the bowel from the mesocolon, especially if the latter is also the site of a hæmatoma or is actively bleeding
(c) The vitality of the bowel is crushed out of existence by a large piece of metal or other fragment hurled with all force of high explosive
(d) The wound of the large intestine has been of such magnitude or difficulty of approach as to suggest the formation of an artificial anus

In this last group resection is worthy of consideration when the high mortality of the colon anus in the 1914 18 war is borne in mind. A temporary or prophylactic cæcostomy proved of inestimable value in the writer's hands in colon resections

Attention may appropriately be directed here to the gangrenous ulceration of the mucous membrane of the more fixed parts of the large bowel to which Hamilton Drummond and Shaw Dunn first drew attention This very rapid *gangrene of the mucous membrane seems* to be caused by the deprivation of its blood supply through the rupture of the small vessels and laceration of the underlying muscular coat of the bowel produced by a missile the actual track of which may be separated by *some distance from* the intestine In these bursting or traction injuries gangrene of the bowel leads almost at once to a severe infection of the retroperitoneal space colostomy can be of no more service in this class of case than the performance of an enterostomy in the treatment of a gangrenous appendicitis Resection along with lavish drainage and sulphonamide therapy offers the only hope

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CHAPTER XLII

WOUNDS OF THE RECTUM AND BUTTOCKS

RECTAL wounds more often than not are extremely serious and adequate treatment is usually difficult. The mortality is very high especially if the intraperitoneal portion is injured. A rectal wound must always be expected whenever there is a wound of the buttock or bony pelvis or an oblique wound from the flank to the thigh.

Speaking generally, penetrating wounds of the pelvis are more serious than penetrating wounds of the abdomen because the parts are not so accessible and because the retroperitoneal tissue of the pelvis with its abundance of fascia is almost invariably infiltrated with blood and so is very prone to infection.

Sir John Fraser applied the term "colon septicæmia" to this retroperitoneal infection which is so frequently met with when the fixed colon is wounded and is so common in rectal wounds.

The clinical features of colon septicæmia—Fraser described the condition as follows: "The signs may appear and develop with startling suddenness. Patients suffering from this condition have generally a grey pallid appearance and it suggests that there has been an extensive loss of blood, but investigation of the history will show that this has not been the case. There is restlessness and great uneasiness. Signs of delirium appear and become established. The pulse is characteristic; from the normal rate it very rapidly increases so that in the course of a few hours it may have reached a speed of 150 a minute. The respiration rate increases until it reaches 40 to 50 a minute, the temperature behaves variously: in the most intense cases it falls to subnormal and remains so, in less acute cases it rapidly rises to a considerable height (104° to 105° F.), and shortly before death it falls with a crisis. Vomiting is common, frequently in mouthfuls, ultimately resulting in acute dilatation of the stomach. Before death the delirium passes into complete loss of consciousness and the general pallor is replaced by a slightly jaundiced appearance."

This is a classic description. It may well be that in the future the prompt use of sulphonamide preparations in addition to early and efficient surgery will make colon septicæmia less frequent.

The late Hamilton Drummond, in 1919 at the Royal Society of Medicine, reported on sixteen cases of gunshot wounds of the rectum which had come under his observation. Fourteen of these cases had died, and the two main factors resulting in death were infection of the retroperitoneal tissues and shock. These are the results in the hands of a man who was specially trained in civil rectal surgery and was a brilliant surgical specialist at a casualty clearing station in the 1914-18 war.

Wounds of the rectum may be —

1 Intraperitoneal
2 Extraperitoneal
3 A combination of both

Intraperitoneal and combined intraperitoneal and extraperitoneal wounds—The entrance wound is usually through the buttock or sacrum and fracture of some portion of the pelvis is a common complication when the wound of the rectum is intraperitoneal The bladder and coils of small intestine in the recto-vesical pouch are often injured Hæmorrhage from the large vessels in the pelvis may be an added complication

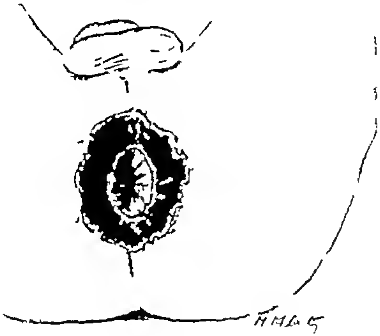

Fig 348
Explosive wound of the perineum.

When the intraperitoneal portion of the rectum is injured from behind or from the side the retroperitoneal tissues cannot escape some damage from blood or fæcal extravasation although a fæcal escape is not common unless there is extensive laceration of the bowel As in wounds of the large intestine subsequent infection (streptococcal and anaerobic) readily follows unless adequate surgery and drainage are employed sufficiently early In some instances a missile may pass transversely behind the rectum damaging the retroperitoneal tissues but not actually wounding the rectum.

Extraperitoneal wounds of the rectum are less common than intraperitoneal They frequently result from a transverse bullet wound through the hip and the injury may easily escape notice unless there is bleeding from the anus or retention of urine In one instance of a bullet wound through the great trochanter a wound of the rectum was not suspected until the patient passed wind through the great trochanter with a high musical note Wounds of the extraperitoneal portion sometimes produce a remarkable explosive effect in the perineum, especially when the missile passes superficially across it, and I have seen more than one instance of a perineal burst resulting in isolation of the sphincter surrounded by a ring of skin which had been torn away from the surrounding skin This suggests that at the time of impact the sphincter contracts violently and holds tight while the concussion of the missile in the loose tissues bursts the skin around it like "popping a closed paper bag" (Fig 348) The sphincter is drawn so high up that at first sight it appears as if the anal canal had been shot away Unrecognized or untreated wounds of the extraperitoneal portion may at a later date give rise to complicated fistulæ

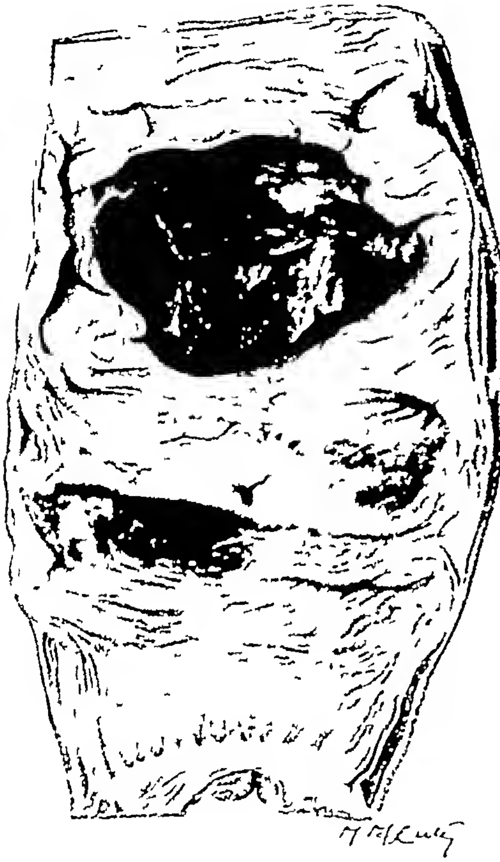

FIG. 349

From a man admitted on 11th September 1916 and who died thirteen hours later Rectum laid open In the mucosa there are two patches of ulceration covered with blackish slough The third, fourth and fifth sacral bodies had been destroyed by a fragment of shell The rectum was exposed, its outer wall being apparently intact, but blackened The ulceration is remarkably advanced considering the short time elapsing between receipt of the injury and death (W O Coll, R C S 1187)

After the last war a man was under my care at St Mark's Hospital who had been transferred from an orthopædic hospital where he had been treated for suppurative arthritis of the left hip There were numerous sinuses in the ischiorectal fossa and in the thigh right down to the popliteal space, and all were communicating There was a scar of an old entry bullet wound in the left flank and no exit wound had been noted

On investigation it was found that there was a hole in the ampulla of the rectum on the left side The bullet had no doubt been lodged in the rectum and passed with a motion All the subsequent troubles had followed a perirectal infection

On another occasion when operating on a *fistula-in-ano*, I removed a bullet from the ischiorectal fossa This patient had been wounded in the thigh during the war some years previously

Drummond called attention to the fact that in some instances a severe blow on the sacrum produced a laceration of the underlying vascular tissue and rupture of the small vessels, resulting in very rapid gangrene of the mucosa of the gut (Fig 349), a condition which may occur as early as seven hours after the infliction of the wound

He pointed out that colostomy was of little service in these cases unless the gangrenous patch was excised and the retroperitoneal tissue drained

TREATMENT OF INTRAPERITONEAL WOUNDS

In every case it is necessary to explore the abdomen

A most important practical consideration is that wounds in the buttock or back must receive attention *before* the abdomen is opened This contravenes a general principle in the abdominal surgery of warfare namely that entrance and exit wounds are dealt with after performing laparotomy (see p 397) When either the entrance or the exit wound leads to the extraperitoneal pelvic tissues very free drainage should be provided If this can be carried out adequately before the abdomen is opened one is spared the necessity of turning the patient Practical experience has proved conclusively that shock is always severe if patients are turned over after laparotomy Turning the patient after laparotomy should be avoided if possible and it can be avoided by forethought

An accessible perforating wound of the rectum is found. The perforation should be sutured with a double layer of thread or fine silk

We will assume that the perforation has been closed satisfactorily hæmorrhage controlled and the toilet of the peritoneum completed There are now three cardinal considerations —

1 Is THE DRAINAGE OF THE EXTRAPERITONEAL TISSUES SATISFACTORY ? If not it may be possible for an assistant to insert a drainage tube into the entrance or exit wound and for the operator to manipulate it into the desired position Drainage of lacerated and infected retroperitoneal tissues is essential and when the measures outlined fail to effect such drainage it is more than justifiable to take the additional risk and to half turn the patient over[1] Through a vertical incision above the anus the coccyx and perhaps even a portion of the sacrum are removed This gives marvellous access to the retroperitoneal rectal cellular planes

2 SHOULD THE PERITONEAL CAVITY BE DRAINED ? There is no doubt that in this instance where fæcal contamination has assuredly occurred suprapubic peritoneal drainage should be carried out as a routine

3 Is A TEMPORARY COLOSTOMY NECESSARY ? In my opinion it is wise to perform a temporary colostomy in nearly every case In the type of lesion under consideration left inguinal colostomy is ideal

Finally it is good practice to stretch the anal sphincter insert a large rubber drainage tube and fix it in position with a stitch

The rectal wound is inaccessible or an extensive laceration is present. Amidst infiltrated tissues deep in the recto-vesical pouch it is often extremely difficult to find a perforation of the rectum On other occasions an extensive laceration incapable of being sutured satisfactorily will be encountered In both these circumstances the only hope lies in diverting the fæces providing free drainage and attempting to shut off the general peritoneal cavity Colostomy is essential. It should be performed with clean instruments and after changing the gloves Whether the colostomy should be

[1] Sometimes turning the patient can be avoided by employing the lithotomy position for removal of the coccyx, but the procedure in the lithotomy position is more difficult

in the pelvic or transverse colon depends to some extent on the nature of the rectal injury If a subsequent plastic procedure is likely to be required a transverse colostomy is indicated, as this will enable mobilization of the pelvic colon Transverse colostomy is essential if there is hæmorrhage into the mesentery of the sigmoid

FIG 350
Shell wound of the buttock which involved the rectum and the bladder The patient recovered with appropriate treatment Lt Col Butler's case (*British Journal of Surgery*)

Free drainage of the retroperitoneal tissues follows the principles detailed already In some instances it is possible partially to shut off the general peritoneal cavity by attaching omentum to the rectum above the laceration When feasible this "shutter" operation should be carried out Alternatively the recto-vesical pouch can be packed lightly with a roll of gauze soaked in flavine brought out through the lower end of the laparotomy incision The gauze is removed after forty-eight hours Packing should be avoided unless the circumstances are desperate

The abdomen is closed with adequate drainage of the recto-vesical pouch The patient is now placed in the lithotomy position An incision is made in the middle line from the anal verge towards the tip of the coccyx, and the external sphincter is divided completely A large drainage tube is passed into the rectum and secured to the skin by a stitch

FIG 351
The lateral sacral incision for draining the pelvi rectal cellular tissues

As has been mentioned earlier in this article, extensive injuries of the rectum present a very difficult problem Desperate conditions may demand desperate measures So disappointing were the results of conservative measures during the last war that some operators inclined to radical excision of the rectum as a possible panacea I still would counsel cleansing, drainage, colostomy and, if necessary packing Now that the necessity for free drainage of the retroperitoneal tissues is fully realized that the facilities for blood transfusion are far greater than they were twenty five years ago and that we have at our *command* the sulphonamide group of drugs perhaps some much needed improvement can be expected

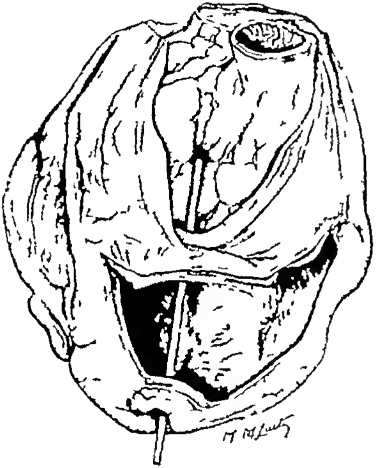

FIG. 3.

A bladder and rectum viewed from above the fundus of the bladder having been cut away A rod of white glass has been passed through a gunshot track which courses from before backwards through the bladder across the recto-vesical pouch and through the rectum. The exit in the posterior wall of the bowel is large enough to admit a finger (W O Coll, R.C.S., 1173.)

EXTRAPERITONEAL WOUNDS

One would imagine the prognosis in extraperitoneal wounds of the rectum would be far less grave than the intraperitoneal variety and so they should be Unfortunately only too often these injuries are unsuspected until that hugbear of rectal wounds—pelvic cellulitis—is established fully This to a large extent can be remedied if the surgeon benefits by the experience gained in the last war Every penetrating wound in the region of the buttock (Fig 350), and even lower, should be suspected of having damaged the rectum until it is proved otherwise When the pelvic cellular tissues can be drained early and adequately, drainage of the rectum via a divided sphincter (*vide supra*) is often sufficient, but again it is emphasized that if any doubt arises in the mind of the operator as to the efficiency of these measures, left inguinal colostomy should be performed in addition

For wounds of the buttock involving the rectum an incision lateral to the sacrum (Fig 351) is often extremely useful, giving as it does good access to pelvi-rectal cellular planes

The incision extends from just behind the anal margin and runs upwards alongside the coccyx and the lower three segments of the sacrum The incision is deepened and extends through the levator ani to reach the pelvi-rectal cellular tissues

When the bladder is damaged in addition to the rectum (Fig 352), one should, if possible, deal with the bladder injury first (*vide* Chapter XLV) When it is necessary to perform colostomy in addition to suprapubic cystostomy, the bladder should be closed accurately about a de Pezzer catheter and the colostomy wound should be separated from the suprapubic cystostomy wound by the erection of a flexible adhesive plaster barrier With careful nursing and by the maintenance of this barrier, it is quite feasible to avoid infection of the bladder wound from the colostomy.

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It has been shown in this chapter that wounds of the buttocks require special care and attention As will be seen in Chapter XLV, the bladder is also frequently implicated, in Chapter XLV, wounds of the buttock are referred to again The high incidence of secondary hæmorrhage in wounds of the buttocks is discussed in Chapter XXVI The importance of these wounds and the necessity, when possible, for their thorough excision cannot be overemphasized A method of nursing these cases is described in Chapter LVII on "The Use of Thomas' Abduction Frames"

CHAPTER XLIII

POST-OPERATIVE ABDOMINAL COMPLICATIONS

WE are concerned here not in dealing with the post-operative treatment of abdominal surgery for a knowledge of this is assumed and it can be amplified by a reference to other works rather the object of this chapter is to set out those complications which experience has shown are to be expected frequently after laparotomy for war wounds

Shock is the commonest and one of the most serious complications The immense value of pre-operative resuscitation treatment has been emphasized (see pp 44 104 and 300) In spite of such treatment post-operative shock is bound to be sufficiently in evidence to give rise to anxiety in a high proportion of cases Shock requires immediate and energetic treatment on the lines set out in Chapter V Amongst the measures of particular value in these abdominal cases are administration of suitable doses of morphia plasma transfusion by the drip method and oxygen administered by the B L B mask Where there has been loss of blood a blood or plasma transfusion should be given even though the patient's condition appears satisfactory

Peritonitis—In all abdominal wounds where the peritoneum is involved the patient must be treated as a case of peritonitis and as soon as shock has been combated the main attention is fixed on this aspect of the case

The patient is raised into Fowler's position gradually Intestinal peristalsis must be reduced to a minimum nothing is given by mouth for at least thirty six hours but fluids are administered intravenously When signs of peritonitis persist after forty-eight hours glucose saline should be replaced by plasma in order to maintain a normal level of blood protein Polyvalent anti-streptococcal serum (80 to 100 c c or its equivalent of the concentrated serum) and sulphapyridine (2 gm in solution four hourly) are given by injection to combat the infection Vitamin B (10 000 to 15 000 units daily) is also helpful Pain and restlessness are met by the suitable sedatives As the abdominal condition improves sips of glucose barley water and fruit juice are given by mouth

An important consideration is that no aperient is administered for at least seven days but about the third or fourth day an olive oil or glycerine enema should be given and this may be all that is necessary in order to secure bowel movement

Paralytic Ileus—A mild degree of ileus occurs after most abdominal operations Following laparotomy for war wounds *it is invariable and* constitutes a complication of the first magnitude That the condition is truly paralytic ileus as opposed to what may be termed distension without paralysis is apparent when the distension is accompanied by an increasing pulse rate As this serious condition becomes fully established auscultation of the abdomen reveals no gurgling It is difficult to be sure how many of the symptoms and signs are due to paralytic ileus and how many to peritonitis, as so often the two conditions go hand in hand

Many operations were performed during the 1914-18 war in an attempt to alleviate advanced paralytic ileus they consisted in enterostomy, jejunostomy and anastomosis between the parts of bowel above and below the injured area they met with little or no success

As in civil practice, the treatment of paralytic ileus is now essentially a matter of energetic non-operative measures Distension must be relieved This is accomplished by a duodenal tube or better still, a Miller-Abbot tube which is allowed to remain *in situ* (Fig 353) to syphon off the intestinal contents The blood volume and the blood protein, the latter being more important than the former must be maintained by an intravenous drip of saline and glucose and plasma The aim is to keep the patient alive until the intestinal musculature has regained its tone Small, repeated doses of morphia help in this respect and also rest the patient As infection is a

Fig 353
The Miller Abbot tube in position

major factor in the production of paralytic ileus in war wounds, the general measures outlined to combat peritonitis should be pursued energetically In the distressing complaint of paralytic ileus anything of help is well worth trying Oxygen has been experimentally proved to have a marked effect on intestinal distention and on intestinal movements Vitamin B is also helpful

Post-operative intestinal obstruction—A constant vigil must be kept for mechanical intestinal obstruction, as opposed to paralytic ileus If it is decided that the probabilities are that the obstruction is mechanical, operation must not be delayed During the 1914-18 war, intestinal obstruction from hard fæcoliths in the large gut was a not uncommon occurrence These fæcoliths must be softened by olive oil or hydrogen peroxide, 1 oz to 1 pint of water, or removed manually per anum

Vomiting is a common sequel of these abdominal operations In many cases it is due to the same causes as in civil practice In war surgery special causes are the vomiting of acute toxæmia associated with gas gangrene, intestinal obstruction (paralytic and mechanical) and renal inefficiency In the vomiting due to gas gangrene treatment is essentially that of the infection

Where there has been a crush injury associated with the abdominal wound, the possibility of renal failure must be kept in mind The urine of these patients should be kept alkaline and their urinary output watched carefully. If facilities exist the blood urea is estimated. Any sign of renal deficiency is met by intravenous sodium sulphate (42.3 gm to 1 litre) along with measures to keep the blood volume normal in quality and quantity. A patient with poor renal function may become uraemic by the loss of fluid due to vomiting. Such a patient may start to vomit on account of intestinal obstruction and later—even if the obstruction has been relieved—continue to vomit on account of uraemia.

Another viewpoint to be considered is that when vomiting is long continued the balance of blood protein and salts is upset. On account of vomiting the blood plasma may be so lowered that a large intake of intravenous saline causes death by excessive dilution of blood proteins. It is in this type of case that a plasma transfusion might well save the patient; intravenous fluid therapy must always be associated with a reasoned consideration of the chemistry of the patient's blood.

Infection of the laparotomy incision—After taking into consideration the type of intraperitoneal lesion usually encountered, serious infection of the laparotomy incision does not supervene as often as would be anticipated. Some contamination of the layers of the abdominal wall is inevitable when the bowel has been wounded; consequently it is wise to insert a drain at any rate in the subcutis at the lower end of the incision. With a view to preventing infection of the abdominal wall by the clostridia, sulphanilamide powder should be smeared on to the muscle surfaces of the abdominal wound before closure.

Gas gangrene of the anterior abdominal wall is seldom seen; on the other hand, attention has been drawn to the extreme gravity and frequency of anaerobic infections of retroperitoneal wounds (see Chapters XLI and XLII).

Eventration—When a laparotomy incision bursts asunder usually several predisposing causes are in evidence. Foremost is infection of the laparotomy wound. Obviously abdominal distension and strain due to coughing can play important parts. The timely recourse to abdominal corsettage (see Chapter XV), necessary as it is at all times, should be almost a routine when any of these predisposing factors are in evidence. Eventration sometimes occurs apart from obvious infection of the wound and even in the absence of any one of the easily understood predisposing factors cited above. It has been shown that lack of vitamin C and lack of blood protein both prevent the proper formation of fibroblasts. A serosanguinous discharge about the fifth to twelfth day on dressings which previously had been dry suggests the possibility of failure of the deeper layers of the wound to unite, and appropriate steps should be taken forthwith.

Immediate treatment of a burst laparotomy wound must be undertaken with full surgical ritual. Local anaesthesia supplemented by intravenous anaesthesia if necessary is probably best under these difficult circumstances. The eviscerated parts are washed in saline and returned to the abdomen and the wound closed with the stoutest silkworm gut sutures passing through all layers. In the presence of gross sepsis it is preferable to reduce the number of these sutures to the minimum compatible with the situation and to rely mainly on the use of adhesive strapping for bringing the wound together. It is essential to establish drainage at the lower end of the wound.

When the patient's general condition does not permit resuture, or where the abdominal distension is such that it appears impossible to bring the abdominal wall together, a vaseline gauze pack applied in such a way as to form a false peritoneum, combined with strapping the abdominal wall has proved effective more often than would be imagined. Ogilvie's method of stitching a vaseline cloth to the edges of the peritoneal surfaces of the wound (see p. 401) is also an expedient which should be before one under these difficult circumstances.

Secondary hæmorrhage from the laparotomy wound—Palliative measures are useless. With a drip blood transfusion in progress the patient should be fully anæsthetized and the wound reopened under a good light. The bleeding point or points should be sought and dealt with as required. Hæmorrhage from the anterior abdominal wall is usually easily controlled, especially if a main vessel such as the deep epigastric can be ligatured in healthy tissue. Secondary hæmorrhage from a retroperitoneal wound is much more difficult to deal with. It is one of the most serious complications, particularly when the wound involves the colon. If the bleeding point cannot be found the retroperitoneal wound must be left widely opened and hæmorrhage controlled by packing.

Complications following wounds of the stomach—The after-treatment of wounds of the stomach is conducted on lines similar to those employed in perforated peptic ulcers, but unlike the latter, sutured gastric wounds show a curious liability to develop ulceration about the fifth day and this complication may be associated with secondary hæmorrhage. Armed with this knowledge, the diet must be regulated with even more caution than in the corresponding lesion of civil life.

The patient should invariably be grouped in anticipation of hæmorrhage.

Another complication is subphrenic abscess. It is a sequel of wounds of the lesser curvature, particularly those occurring in the neighbourhood of the cardiac orifice.

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CHAPTER XLIV

WOUNDS OF THE KIDNEYS

OWING to its position in close proximity to other important organs a wound of the kidney is as frequently as not associated with damage to other structures and particularly structures within the chest and abdomen In treating a war wound of the kidney therefore we are frequently called upon to treat also wounds of the small intestine colon and stomach At the same time because the kidney lies deep in the abdomen and partially protected by the bodies of the vertebræ it often escapes the ravages of missiles that perforate the abdominal wall Thus Sir Cuthbert Wallace in his paper on abdominal wounds written in 1917 reports that only in 7 5 per cent of perforating gunshot wounds of the abdomen were the kidneys found to be involved

Even when the entrance wound is situated in the lumbar region and the exit is found in front the kidney often escapes Every surgeon with experience of the last war remembers instances where a missile after perforating the skin and possibly the first layer of abdominal muscles was deflected along the abdominal wall finally to escape in front without ever having perforated the peritoneum Elastic structures that give before a missile have a remarkable power of stopping or deflecting projectiles especially when they are in layers like the walls of the abdomen

Occasionally a kidney is injured even although the bullet does not actually touch it With high velocity projectiles the concussion produced by a bullet traversing a neighbouring structure may be such as to cause a subcapsular rupture of the kidney A similar injury may also be caused if after being hit the patient is buried by the falling in of a wall of a trench or of masonry

Classification—Wounds of the kidney are best classified into —

1 Those involving the hilum and
2 Those involving the parenchyma of the organ

Wounds of the hilum may be subdivided into two categories namely those involving the vessels and those involving the pelvis

(a) *Those involving the vessels*—Should the main renal artery be injured the patient usually dies before he reaches the C C S but if only a branch be divided the hæmorrhage is not necessarily fatal. It is important to remember however that the arteries supplying the kidneys are *terminal* although the veins anastomose For that reason damage to a branch of the renal artery is likely to result in necrosis of a portion of the kidney (Fig 334) This partly explains the frequency of infection following renal injury

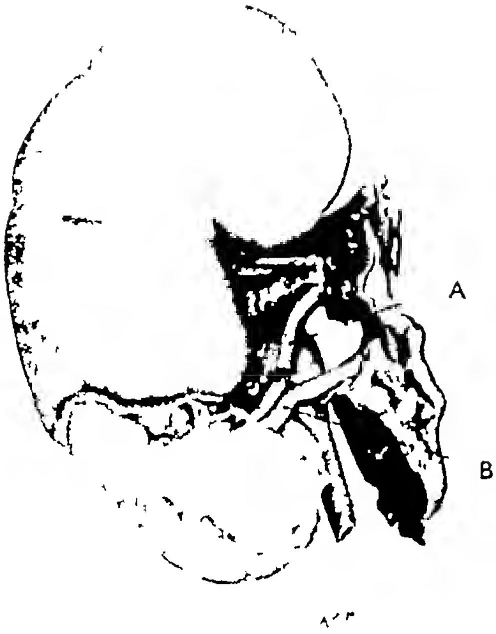

FIG. 354
Injury to a branch of renal artery causing necrosis of the lower pole of the kidney A, Branch of renal artery B, Branch of renal vein (*British Journal of Surgery*)

(b) *Wounds involving the pelvis of the kidney*—These are less frequent than the former type of injury If the peritoneum has been damaged, urine may leak into the abdominal cavity and cause peritonitis Otherwise urine escapes through the wound in the parietes, so as to form a urinary fistula

WOUNDS OF THE PARENCHYMA OF THE KIDNEY

These may be so severe as to reduce the whole organ to pulp, or else so trifling as to be difficult to locate The character of the wound will depend on the nature, size and velocity of the missile (Fig 355) Frequently the calyces are involved as well as the parenchyma, but urine is only likely to escape when the damage is so extensive as to implicate the pelvis

Signs and symptoms—These are as follows —

HÆMATURIA, which may be microscopic, moderate or profuse If there be any doubt as to whether the blood is coming from the kidney or the bladder, cystoscopy is necessary It may be said that hæmaturia is invariably associated with wounds of the kidney unless the ureter is completely divided or the injury is confined to the parenchyma and of small extent

SHOCK—This in uncomplicated cases is not usually severe If very marked, it suggests that the renal wound is complicated by injury of the spine thorax or abdominal viscera

LOCAL CONDITION—Tenderness and rigidity of the abdominal wall are noted in most cases These signs, in conjunction with a wound in the lumbar region from which blood and urine is escaping render the diagnosis certain, although it may be difficult or impossible to state whether organs in addition

FIG 355
The small aperture of entry is seen in the inset The larger exit wound at the opposite surface exhibits well the protrusion of the renal parenchyma The lacerated capsule has receded some distance (*British Journal of Surgery*)

to the kidney are implicated Abdominal distension does not necessarily mean that the abdominal viscera have been perforated since it may be noted in a purely renal lesion A tumour in the flank due to perirenal extravasation of blood is sometimes palpable

X ray examination.—When possible stereoscopic radiograms should be taken so as to locate more accurately the position of any retained foreign body When the patient is seen several days after his injury and his condition justifies such a proceeding the passage of an opaque bougie up the ureter prior to examination will assist this localization materially It must be remembered that the course taken by a missile once it has entered the body is often erratic so that it should never be assumed that it has traversed all the structures lying on a straight line drawn from the point of entry to the point at which it has come to rest

Treatment—In general terms it may be said that the treatment of gunshot wounds of the kidney should be as conservative as possible In a clean through and through bullet wound of the kidney no surgery is indicated unless there is severe hæmorrhage with increasing dullness in the flank or unless there exists a suspicion that the renal injury is complicated by damage to adjoining viscera In all cases of doubt it is wiser to undertake an exploratory operation As a rule the loin should be explored first through an oblique lumbar incision extending approximately to the edge of the rectus If the track formed by the missile clearly leads to the kidney this should be delivered on to the loin and examined carefully First note the condition of the pedicle Should the main artery or vein or their upper branches have been wounded, nephrectomy is indicated. Should the lower branches only be affected and the renal damage be small, three alternative lines of treatment may be adopted —

1 Packing with gauze
2 Suturing
3 Partial excision

Which of these three measures is chosen will depend on the severity of the hæmorrhage and the nature of the renal wound. When partial nephrectomy is carried out, the excised portion should include all that part of the kidney parenchyma that has been deprived of its blood supply

If the pelvis of the kidney has been opened a small drainage tube should be left in position for two days Repair or excision of the kidney should invariably be followed by deliberate opening of the peritoneum in front of the colon so that adjacent viscera may be examined carefully Although a careful inspection of the adjoining viscera is necessary if the patient is badly shocked or has lost much blood a long time should not be spent in searching for foreign bodies.

Complications—The three great complications of injuries to the kidney are sepsis, secondary hæmorrhage and urinary fistula

SEPSIS—This complication of all war wounds is especially common in the case of injury of the kidney for the following reasons —

1 The wounded kidney is frequently surrounded by a hæmatoma that provides a favourable nidus for organisms

2 The absence of collateral circulation in the kidney, leading to necrosis when an end-artery has been damaged

3 The likelihood of the colon being bruised or damaged so that the neighbouring blood clot becomes infected

Sepsis is best dealt with by the turning out of all blood clots, excision of damaged tissue, good hæmostasis, free drainage, wound irrigation and the use of the sulphanilamide preparations Every effort must be made to combat sepsis if the risk of secondary hæmorrhage is to be reduced

SECONDARY HÆMORRHAGE—When this occurs blood may find its way (1) out of the wound, (2) into the peritoneal cavity, (3) into the retroperitoneal spaces, or (4) down the ureter into the bladder Should the last be the route taken and the bleeding be so brisk as to result in its clotting, additional complications are likely to result, *e g* severe renal colic, penile pain and difficulty in micturition

Fullerton states that out of a total of 42 cases reaching the base during the last war 9 developed severe secondary hæmorrhage that necessitated, in all except one instance, secondary nephrectomy Whilst shell wounds are more likely to be followed by secondary hæmorrhage, bullet wounds producing comparatively small renal damage are not devoid of danger

Very seldom is it possible to save the kidney when this complication has arisen In nine cases out of ten the appropriate treatment is blood transfusion and nephrectomy, provided, of course, the state of the opposite kidney justifies this measure Efforts should always be made to ascertain that such is the case before a nephrectomy is carried out Absence of symptoms on the opposite side must not be taken as evidence of the possession of a sound kidney, for the routine investigation of urological cases reveals many instances of unsuspected calculus, hydronephrosis and tuberculous disease Unless, therefore, the condition of the patient brooks of no delay, cystoscopic and radiological examination should be carried out before nephrectomy is performed It must be realized that when the renal pedicle is surrounded by infected blood clot it is very friable, and a mass ligature around its constituents is liable to cut out For this reason, when undertaking nephrectomy under these conditions, it is essential to exercise special care in applying ligatures to the renal vessels Segmental ligation (Fig 356), by which is meant ligature of the pedicle in sections as opposed to a single ligature surrounding the whole pedicle, should be the unwavering rule

PERSISTENT URINARY FISTULA—This is more likely to be a trouble when the pelvis or ureter has been wounded or when a laceration of the parenchyma extends deeply into a calyx If the parenchyma alone is involved, a fistula is unlikely to be a sequel

The leakage of urine may appear at once or be delayed, in which case it is presumably due to separation of a slough More exact knowledge of the nature of the fistula can be obtained by retrograde pyelography and noting where the opaque fluid leaks out of the urinary track

Many cases of urinary fistula heal spontaneously, although it is to be expected that a certain number will show signs of hydronephrosis in future years If there is evidence that the urine is not escaping freely but is first accumulating in a cavity better drainage must be provided Should the fistula persist either a plastic operation or else nephrectomy is indicated

Results—*Half of the patients with war wounds of the kidney who* reached a base hospital during the last war recovered and according to the statistics of the American Expeditionary Force 16 per cent of them without any operation When we remember the frequency with which wounds of other viscera are associated with injury of the kidney these results are surprisingly good In fatal cases the patient dies usually from hæmorrhage

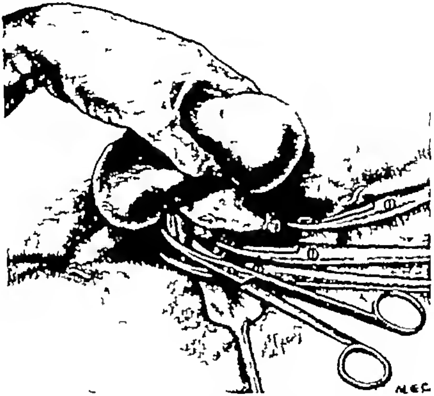

Fig 336

Nephrectomy The segmental division of the renal pedicle should be noted This is much safer than a mass ligature

or else from the gravity of the associated injuries so that death takes place in the front area *Analysing results in the more forward area* Fraser and Hamilton Drummond record 17 recoveries and 12 deaths In these 29 cases there were 12 uncomplicated and 17 complicated cases treated as follows 21 by drainage only 2 by suture and drainage and 6 by nephrectomy Wounds of the right kidney proved more fatal than those of the left

No statistics are available for assessing the ultimate results of war wounds of the kidney but it must be realized that a *certain percentage of patients* who are recorded as leaving hospital cured will if examined later be found to be suffering from renal sepsis, calculus or varying degrees of hydronephrosis In spite of this it may be said that the results of the war surgery of the kidney are satisfactory

WOUNDS OF THE URETER

According to the statistics of the last war, injuries of the ureter are exceedingly rare and are generally associated with multiple injuries. Only two uncomplicated injuries of the ureter were recorded by the American Expeditionary Force, both from machine-gun bullets. Two similar cases are mentioned in British records.

In most cases, owing to the complicated conditions that exist, wounds of the ureter pass unrecognized, and even if the presence of escaping urine suggests to the surgeon the possibility of a ureteric injury, all that need be done is to provide good drainage. No case of immediate repair by suture has yet been reported. Should a persistent fistula result, a fuller investigation is called for, followed either by a plastic operation or else by nephrectomy.

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CHAPTER XLV

WOUNDS OF THE BLADDER

INCIDENCE.—According to the "British Official History of the Great War" the bladder was perforated forty five times in a series of 965 abdominal casualties operated upon (4.66 per cent.) whilst the corresponding American publication gives 3 per cent. Tanton collected only 35 examples of bladder wound from the communications of a large number of French surgeons.

Surgical anatomy—The empty bladder is a small object and therefore an insignificant target. As the bladder fills with urine the upper wall rises and in full normal distension (10 to 15 oz.) the vesical dome is lifted above the symphysis pubis. The height which it reaches is not however in health more than 1 in. or at the most 2 in. This relatively small area is all that is exposed to a missile traversing the anterior abdominal wall from the front.

A full bladder is obviously a larger target than the empty organ (Fig. 357).

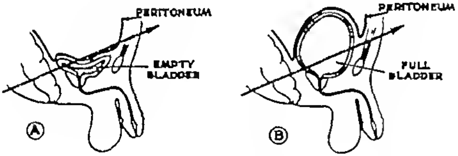

FIG. 357.

Showing the great difference as to whether the bladder is (a) empty or (b) full at the time of wounding.

(*After Kirkpatrick.*)

Much discussion has concerned the question whether a soldier would go into action with a full bladder or whether the stress of anticipation would not compel him to urinate. Larrey observed that the veterans of the Empire who in the heat of action could forget to empty their bladders were more exposed to vesical injuries than the conscripts in whom the fight caused polyuria or even incontinence. The question is less important to-day when pre-arranged attacks with a "zero hour" are less common than in the last World War. Unexpected onslaught from the air is responsible for a higher proportion of injuries than ever before, and the distension of the bladders of its victims will be fortuitous.

The level of the reflection of peritoneum from the bladder on to the abdominal wall rises as the bladder fills but not *pari passu*, so that if the vesical dome has risen to a point 2 in. above the pubis the peritoneal reflection will be, say, 1 in. only above the pelvic brim. The depth to which the peritoneum sinks posteriorly into the recto-vesical pouch requires no description.

The evolution of the case and its treatment are fundamentally affected by the involvement or not of the peritoneum *Intraperitoneal* wounds which occur when the dome and posterior wall of the bladder are involved, lead to peritonitis and are generally complicated by wounds of the small intestine and pelvic colon *Extraperitoneal* wounds affect the anterior wall lateral walls and base of the bladder They lead to extravasation of urine into the cellular spaces of the pelvis and pelvic cellulitis Many are complicated by wounds of the rectum and anus

Tanton found that extraperitoneal wounds of the bladder outnumbered the intraperitoneal wounds in the proportion of about four to one (266 to 68) Extraperitoneal and intraperitoneal injuries are frequently combined

The course of the missile—It is natural to think of gunshot wounds of the bladder as entering by the hypogastrium and having a roughly antero-posterior direction This conception has a measure of truth in the case of rifle and machine-gun bullet wounds, but statistics of the 1914-18 war show that most bladder wounds were produced by high explosive shells and shrapnel (Fig 358) and were oblique in direction

FIG 358

Cystoscopy twelve days after wounding revealed a shell fragment ulcerating through the bladder wall Note the slough and the surrounding cystitis (Fullerton *British Journal of Surgery*)

The late Andrew Fullerton made a classical contribution to the study of war wounds of the bladder, of which he collected fifty-three examples seen at base hospitals in France He points out that the most severely wounded die on the field or at advanced stations Of his series of fifty-three cases there were only four with an entry wound in the suprapubic region and a further four in which the missile had either emerged by this route or had been retained in the suprapubic region " On the other hand there were thirty-four patients in whom the wound of entry was on the buttock and five with an exit wound in this area *In thirty-nine out of fifty-three cases (nearly 75 per cent) a wound communicating with the bladder was found on the buttock* The sites of other entrance and exit wounds were found further afield on the thigh, groin, perineum, loin and upper abdominal wall

Only about a quarter of all wounds of the bladder are of the penetrating variety All observers are agreed that in a very high proportion of cases the projectile is retained, Fullerton found this to be the case in thirty-three out of fifty-three cases, and it is surprising to learn that in ten of his cases the missile was found in the bladder itself (Fig 359) In twenty-nine cases recorded by Cathelin the entrance wound was situated posteriorly eighteen times, anteriorly seven times and laterally four times Exit wounds were discovered in only four patients the missile being retained in five out of every six cases

When the wound is of the through-and-through variety, reconstruction of the probable pathway may suggest that the bladder has been damaged Similarly, if the missile is retained, radiography will help to reveal its course and destination

Character of the wound—A clean bullet wound tends to split the fasciculi of the bladder musculature. A punctured wound of the bladder is a veritable menace, for it has a way of temporarily sealing itself. At operation, especially when the bladder is empty, it may be impossible amidst the urine and blood clot to discern such a wound.

During the 1914-18 war I remember a post mortem in which a bladder perforation was suspected. Full distension of the organ failed to make it leak, but a hole was eventually found in the retro-trigonal area, the various coats of the organ having overlapped to form a valve. Cases are known in which this type of valve has remained competent for a time and has subsequently allowed extravasation leading to fatal cellulitis or peritonitis.

As in other situations, wounds caused by high explosive shells and shrapnel vary in size, but on the whole tend to produce large irregular wounds of the bladder.

FIG. 359

Wound of entrance and bullet in bladder. Moderate degree of cystitis.
W, wound. U, ureteric orifice. (*British Journal of Surgery*.)

Complications—Of the forty-five examples reported in the British Official History of the Great War, the bladder was the only organ injured in twenty-five cases. Many bladder injuries caused by projectiles are complicated by trauma to one or more of the many important surrounding structures. Most complicating injuries prove to be more dangerous than the bladder wound itself; inevitably they increase the latter's seriousness.

COMMON ASSOCIATED INJURIES

Pelvic girdle—Wounds of the bladder are frequently complicated by compound fractures of the bony pelvis.

In 61 patients suffering from wounds of the bladder Legueu and Gouverneur observed 40 examples of fracture of the pelvis (66 per cent.). Legueu, in a personal series of 50 bladder injuries, saw an accompanying bony injury in 25 (50 per cent.) as follows: the horizontal ramus of the pubis was involved seventeen times and on two occasions fracture of each of the following was observed, the symphysis pubis, the sacrum, ilium and hip-joint.

Of Fullerton's 53 cases, 22 (or 4[illegible] per cent.) showed damage to the bones of the pelvic girdle. The pubic bone itself suffered injury in 12 cases, but with it were combined injuries of the sacrum, great trochanter and upper end of the femur involving the hip-joint, each on a single occasion. In addition the sacrum was fractured five times, and the ilium, ischium and coccyx twice each.

In Tanton's long series there were only 53 uncomplicated injuries of the bladder as against 312 in which fractures of the pelvis were encountered.

When fractured the pubis, being a bone formed mostly of compact tissue, tends to splinter and the fragments are commonly long and sharp. When the more cancellous ilium or sacrum is hit a large piece may be detached

The softer bone, however, shows a proneness to pulverize at the point of impact, and multiple small detached fragments are then to be found scattered about the pelvic cavity.

Occasionally sequestra have been known to separate and, following the track of the missile, have been shed into the bladder. This may occur years after the injury.

A patient received a gunshot wound of the abdomen (1st July 1916) from right to left perforating the small gut (large tear), bladder and left hip. He was treated early by laparotomy and a month later the bullet was extracted from the region of the left hip joint. In August 1921 he developed an acute cystitis and a "flare up" of the wound in the left hip which discharged. In 1927 he developed a urethral discharge and severe pain in the penis. In 1929 I saw him, and a foreign body was palpated in the urethra. It was pushed back into the bladder and a piece of necrotic bone the size of a sixpence was seen with the cystoscope. It was crushed in the jaws of a lithotrite and withdrawn.

The bowel—Only too often the bowel is involved simultaneously with bone and bladder.

In Fullerton's series the following were observed:—

Structures Injured	*Cases*
Bladder, pelvic bone and rectum	11
Bladder, pelvic bone and small intestine	2
Bladder and pelvic bone	9
Bladder and rectum	8
Bladder and small intestine	4
Bladder and pelvic colon	1

Legueu published 60 cases of bladder wounds, in 20 of which (33.3 per cent.) there was a wound of the rectum.

Prostate—When the bladder base is involved, the prostate and the posterior urethra are unlikely to escape, and diagnosis may prove difficult when this complicated area is damaged. An attempt at the time of operation to repair the channel over an inlying catheter is very important.

Two interesting cases, examples of recovery from gunshot wounds involving the posterior urethra, were reported by the writer in 1934. In each of these, though there was no stricture formation, the internal sphincter of the bladder had been destroyed, leaving the external sphincter as sole guardian of the urinary outflow. In each of these patients the absence of a barrier to the backward passage of sperm into the bladder during coitus led to failure of emission and the subsequent passage of the sperm with the urine.

Blood vessels of the pelvis—Wounds of the larger vessels of the pelvis are rapidly fatal from hæmorrhage. Wounds of smaller vessels produce large collections of blood in the bladder or perivesical tissues or in the peritoneum. A large subperitoneal hæmatoma, combined with extravasated urine, and perhaps fæces, has on many occasions made accurate observation difficult.

* * * * * * * *

We are accustomed to think of war injuries in terms of the male, but it should be remembered that, with the development of aerial warfare, women are almost equally liable to be wounded. The special anatomy of the female pelvis may determine bladder wounds complicated by wounds of the female genitalia, including vesico-vaginal fistulæ.

DIAGNOSIS

In the period immediately following wounding shock is liable to be pronounced.

At the time of the injury local pain is severe; it may be definitely referred to the bladder or it may be more general Occasionally an intense desire to micturate culminating in strangury focuses attention on the bladder

Catheterization will demonstrate —

1 The patency or otherwise of the urethra
2 Distension of the bladder if present suggesting that there is no leakage
3 The absence of more than a drop or two of urine indicating that the bladder is perforated An empty bladder suggests an intraperitoneal extravasation but sometimes urine may be withdrawn directly from the peritoneal cavity itself
4 Pure blood or blood stained urine

A study of the portals of entry and outlet will give some idea of the structures which have lain in or near the track of the missile From one or both of these openings urine may be seen to flow and this observation is proof that some part of the urinary system—not necessarily but probably the bladder—has been damaged *Urine escapes more easily* from wounds of those body surfaces which lie in moderately close relationship with the bladder such as the anterior abdominal wall or the perineum Tracks which pass through a considerable thickness of muscle as for instance those situated in the buttock or thigh *often become shut off* For this reason and also because bladder wounds themselves sometimes become sealed spontaneously (p 444) leakage of urine from the surface wound is not observed constantly Another reason why extravasated urine may fail to appear on the surface is involvement of the peritoneum the urine finding an easier outlet into that cavity When the rectum has been wounded along with the bladder it is possible that urine will be passed per anum but this is not usual in the early stages Faeces and flatus may also be passed per urethram or through a cystostomy opening

Prognosis—A gunshot wound of the bladder is a serious injury When uncomplicated the mortality is about 30 per cent The mortality rises steeply in cases complicated by other visceral damage and fracture of the pelvis Intraperitoneal injuries are more fatal than extraperitoneal when the small gut is involved the picture is dismal in the extreme in sixteen instances there was only one recovery (British Official History of the Great War) This is out of all proportion to the results of injuries of the small intestine alone Apparently the bladder lesion turns the scale against the patient

TREATMENT

Early operation is always indicated but as with other wounds particularly those involving the viscera the time must be well chosen Adequate resuscitation is a necessary preliminary

The incision—Only in a few cases when it is centrally situated upon the abdominal wall can the surface wound be utilized to allow operative access to the bladder Usually an independent incision is required, and a median vertically placed one permitting exploration of the peritoneal cavity is recommended

The subsequent stages of the operation depend upon whether the peritoneum is involved or not

Intraperitoneal wounds—Extravasated urine and blood are removed, preferably by suction Unless there is some serious contraindication, the patient is then placed in Trendelenburg's position A wound in the vesical dome is easily accessible, and after its bruised and lacerated margins have been excised it should be sutured with two layers of catgut Before closing the bladder it is necessary to inspect its interior to ascertain whether there is any foreign material therein and to satisfy oneself that a second wound of its base has not been overlooked The sutures are so placed as to avoid penetrating the mucosa, lest they act as a foreign body upon which a calculus might form subsequently Wounds low down in the recto-vesical pouch are sometimes inaccessible, and it may prove easier to enlarge the vesical wound forwards so as to be in a position to stitch the lowest section from within the bladder This manœuvre is particularly valuable when the wound lies partly below the reflection of the peritoneum

Most of these intraperitoneal bladder injuries are complicated by serious wounds of other abdominal viscera , only too often the repair of the wounded bladder is but an important incident in the course of the laparotomy Sutures taking up the peritoneal coat seal the bladder so quickly that a good watertight repair is ensured On this account drainage of the bladder may with fair safety be omitted, and this practice has been followed on many occasions with success Nevertheless there is always the danger that spasmodic retention of urine will put a strain on the suture line The writer therefore advises that an in-dwelling catheter be placed in the urethra for forty-eight hours This practice is essential if the patient has to be evacuated shortly after the operation The toilet and drainage of the peritoneum follow on recognized principles

Extraperitoneal or subperitoneal wounds—These wounds present different problems according to whether the anterior wall of the bladder or the deeper basal parts are involved

The **anterior wall** is usually injured by a missile traversing the suprapubic region, groin, etc Its treatment has much in common with the treatment already described for intraperitoneal injuries, namely, excision of the margins of the bladder laceration, inspection of the interior of the viscus for foreign material and particularly for a second wound, followed by the closure of the bladder wound around a self-retaining tube with adequate drainage of the cave of Retzius Unless the surgeon is quite satisfied that no intraperitoneal lesion has been sustained, laparotomy through a separate (standard) incision (p 398) should be undertaken with fresh instruments and gloves

Many of these anteriorly placed bladder wounds are associated with compound fractures of the pubis (Fig 360) A great loss of the bladder substance sometimes accompanies such an accident, and the outlook is grave In survivors of the inevitable shock, sepsis is difficult to control, and necrosis of bone further complicates the situation Meanwhile the suture line in the anterior wall of the bladder breaks down, and the edges, widely separating from each other, become adherent to the posterior surface of the suppurating pubis The external wound remains open for months, and if and when it does close the anterior wall of the bladder is still formed by the necrotic pubis Cystitis persists and the frequent shedding of small sequestra leads to recurrent stone production

Foreseeing this unhappy train of events the surgeon will —

1 Stitch the bladder with meticulous care using two layers if it is possible to do so without putting tension on the sutures (Tension should be avoided at all costs as the bladder musculature does not tolerate it)

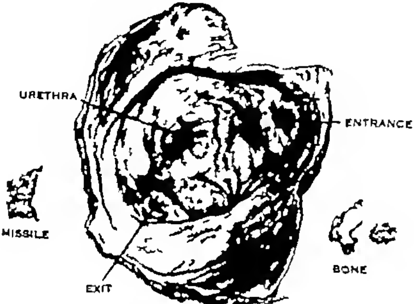

FIG. 300

Through-and through wound of the bladder produced by the shell fragment shown. The missile passed through the pubic bone bladder rectum and sacrum and lodged in the superficial tissues. Note the ecchymosis of the bladder wall and the superficial necrosis of its mucous membrane Death from pelvic cellulitis occurred six days later (Fullerton *British Journal of Surgery*)

2 Keep the suture line as far from the pubis as possible by sinking the bladder into the pelvis and not slinging it to the posterior surface of the abdominal wall. It is rare that there is any fat or other tissue to interpose between the bladder and the bone but this should be looked for and utilized

3 Bring out the suprapubic tube at the upper end of the opening in the bladder and make it emerge an inch or more above the *symphysis pubis so as to forestall* adhesion.

Wounds of the anterior vesical wall form but a small proportion of the extraperitoneal group of bladder wounds though probably many injuries of this description are associated with such grave damage to the symphysis pubis, the pelvic viscera and blood vessels that they do not reach the surgeon

Wounds of the bladder base—The treatment of extraperitoneal wounds of the more deeply placed portions of the bladder constitutes a troublesome and perplexing problem because of the difficulty in repairing them and in supplying satisfactory drainage As before stated, they form a large proportion of all bladder wounds The entrance or exit wounds will generally be found posteriorly, as in the buttock, perineum or thigh, the missile having in many cases traversed a considerable thickness of flesh to reach the bladder and so having left behind it a long and frequently narrow and tortuous track

The four principles of excision, suture, drainage of the bladder and drainage of the cellular spaces of the pelvis, still guide the surgeon, but the anatomical conditions render them difficult to apply, and in many cases a compromise has to be struck between the ideal and the practicable Of the four principles enumerated, proper drainage of the perivesical connective tissue spaces is the one which is of outstanding importance Nature will herself in time heal many bladder wounds if the patient's life can be preserved

The surgical approach to the bladder is the suprapubic one, but in this case the anterior bladder wall is intact and the bladder collapsed and possibly obscured by extravasated blood and urine Having cautiously exposed the anterior wall it is lifted on slings and incised transversely half an inch below the peritoneal reflection A self-retaining retractor displays its interior

The areas of the bladder of which the treatment has already been described (viz, the peritoneum-covered surface and the anterior wall) have been mobile and easily accessible They have lent themselves to excision and reconstruction, but this is not true of the lateral walls and the base The external surface of these sections is applied to a loose but somewhat coarse fibro-fatty layer, which separates them from the sides and floor of the pelvis, and especially from the upper surface of the levator ani muscle and the rectum This fibro-fatty layer immobilizes the bladder walls, which makes surgical handling of them from within the viscus almost impossible

1 For this reason *excision* of wounds of the base is impracticable, and the surgeon has to be satisfied with trimming away necrotic tags or even withholding his hand altogether

2 The *suturing* of the wall from within the cavity is likewise unsatisfactory, for the bladder wall is immobilized by its external relationships In all cases, except those where the wound is quite small, the surgeon should ask himself whether suturing is not better omitted

3 *Bladder drainage* should be free Some surgeons will employ a "catheter à demeure," but a suprapubic drain is more dependable In treating war wounds of the bladder it is a good general principle to envisage the possibility that the patient may be evacuated and fall into less experienced hands

I well remember a patient with a gunshot wound of his bladder who in his delirium removed his catheter, a circumstance which might have been serious had the patient been in transit or surgical assistance not been at hand

Suprapubic drainage is more foolproof than the in-dwelling catheter A small tube is also inserted in the space of Retzius

4 *Drainage of the pelvic cellular spaces* must be the prime consideration

in the treatment of these patients, as a notable proportion of deaths result from pelvic cellulitis The question of drainage of the extraperitoneal tissues has been dealt with on p 420 The teaching given there is equally applicable in this instance In brief it emphasizes that drainage of the pelvic cellular tissues must be free and preferably postero inferior

In cases where posterior drainage has not been used or has proved inadequate an accumulation of pus may form deep in the pelvis A favourite situation for such a collection is the angle between the prostate and the bladder neck

An excellent approach to such a collection is through a curved incision in front of the anus (Fig 361) This is deepened into the ischio rectal fossa and in the mid line the central tendon is divided close to the bulb which is thus separated from the anal canal By careful blunt dissection the wound is deepened and the collection will be felt with the finger lying deep to the levator ani The fibres of this muscle yield easily before pressure with forceps and the purulent collection is entered Good dependent drainage is secured by this route

FIG 361

A curved incision in front of the anus, deepened in the way described in the text is excellent for draining a collection of pus at the bladder neck.

THE TREATMENT OF COMBINED WOUNDS OF THE BLADDER AND THE LARGE BOWEL

When the wound is extraperitoneal it affects the bladder base and that part of the rectum which is in actual contact with it From the standpoint of treatment the fundamental consideration is the fact that these fistulæ tend to spontaneous closure and of this propensity many writers bear witness

In Legueu's series of 60 bladder wounds, 20 had an associated rectal wound. Eighteen of these healed on their own within eight months of their respective injuries—1 of them in a few days, 7 more at or before six weeks, a further 3 in three months, 4 more within six months and the last took eight months to close The remaining 2 died, 1 early the other's wound, which was an extensive one was evidently not going to heal. He succumbed to renal sepsis.

So high a level of spontaneous healing makes any attempt at operative repair unnecessary and, in view of the inaccessibility of the rectovesical fistula unjustifiable As fæces will for a time pass through the bladder a cystostomy must be performed and the tube should be an open-ended one of generous size so as to anticipate blockage with fæces It will be retained until there is good evidence of complete healing of the fistula and throughout convalescence special attention will be devoted to bladder lavage *not only to control sepsis but also* for the mechanical removal of bowel contents

The value of a colostomy in wounds of the rectum has been emphasized in Chapter XLII Should a colostomy be called for in combination with a cystostomy, a transverse colostomy offers advantages over an iliac colostomy —

1 It is farther away from the cystostomy wound
2 It leaves the sigmoid mobile should a further operation in the region be called for
3 When the time comes a transverse colostomy is closed easily

For method of dressing a case with a combined colostomy and suprapubic cystostomy see p 151

THE POST-OPERATIVE CARE OF BLADDER INJURIES

The older methods of draining the bladder into wool, moss pads or a Hamilton Irving receiver are now obsolete, and from the foregoing it will be evident that amongst war injuries there is little application for primary closure of the bladder When the bladder has been freely opened closure round a tube rarely gives a watertight joint Urine leaks into the prevesical and perivesical spaces with immediate or delayed infection, and retarded wound healing follows from suppuration and local tissue necrosis The patient, moreover, suffers great discomfort from lying in urine-soaked surroundings In any system in which the bladder is allowed to fill and overflow these dangers are inherent

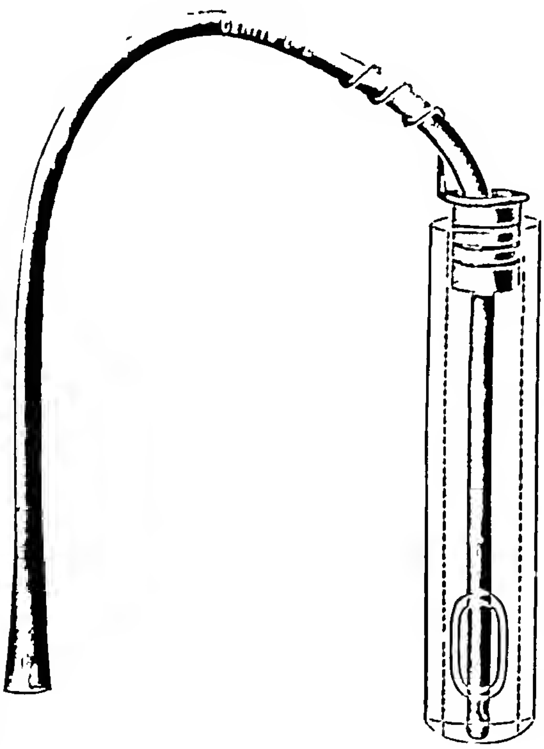

Fig 362

Stedman's tube The Stedman fitting enables a rubber catheter to be retained within a Marion's tube

For many years the writer has been accustomed to maintain a dry bladder by means of suction This involves the removal of the fluids from the vesical sump as soon as they enter The apparatus required consists of a suitable tube for the bladder and a power unit to suck The Stedman tube (Fig 362) has an external drainage tube which differs little from that previously in general use At its outer end a metal clip holds in position a catheter so arranged that it reaches to within a quarter of an inch of the lower end of the outer tube, and so when suction is applied to the outer end of the catheter there is no possibility of bladder mucosa getting damaged by being sucked into the catheter eye

The outer tube is important The output of urine—say 2 to 4 oz per hour—is insufficient to keep the catheter full, and an air inlet must be supplied if negative intravesical pressure is to be avoided This is the function of the outer tube

The power may be provided by a water pump, an electric pump or by other means. In my hospital wards certain beds are connected up to a water pump situated in an adjacent room. This does not involve loss of water because the water used not being contaminated in any way is returned to the general hospital system.

The small electric pump shown in Fig. 363 is the most suitable device where water is not available and is used by me for nursing home work. It is reliable almost silent, and gives a sufficiency of power It rests on a small stool at the bedside and at a level somewhat below that of the bed.

If neither of these methods can be applied a Higginson syringe may be substituted It calls for regular attention at ten minute intervals, but the additional trouble is amply rewarded by the favourable progress of the wound and the comfort of the patient

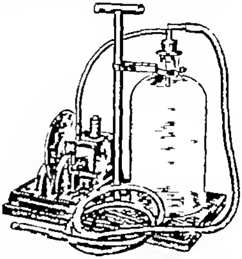

Fig 363

Silent suction pump

(G U M facturing Co.)

When suction drainage is adopted it cannot be satisfactorily cared for under the bedclothes A division is made in the patient s coverings the lower lot extending up to the pubis and the upper down to the umbilicus The wound remains un covered and it is protected from the edges of the bedclothes by sterile towels Two little pillows lie against the patient s buttocks for purposes of warmth and a thickness of cotton wool overlies the iliac fossae and comes to within 3 in of the wound

In ordinary civilian practice the suction continues uninterruptedly for sixty hours when both the suction tube and the prevesical drain may be removed Wound healing and the shutting off of tissue spaces has by that time progressed so far that it can withstand urinary contamination From the time of the removal of the tubes however catheter drainage is relied on and is generally found capable of keeping the wound dry In the treat ment of severe wounds of the bladder it may be thought desirable to con tinue suction for a further period so as to allow more advanced repair to take place and there is no disadvantage in so doing Healthy wound margins fall together almost as soon as the tube is withdrawn and they seal across quickly even after more prolonged drainage than is customary

From the fourth day onwards the bladder should be gently irrigated through a syringe fitted to the indwelling catheter It is important that it should not be overdistended and no more than 1 or 2 oz. should be intro duced at one time This fluid is allowed to escape and the process is repeated a few times The lavage may be carried out morning and evening or more frequently according to the requirements of the individual case The factor which counts is the mechanical cleansing the choice of solutions to be employed being not so important Simple lotions are however to be preferred to stronger antiseptics and sterile water boracic (saturated solution) and potassium permanganate (1 in 8000) are the most suitable

The indwelling catheter is retained throughout the closure of the vesical wound When during bladder washing the wound has shown itself water tight for forty-eight hours the catheter may be removed. If however an injury has involved the bladder base and especially the internal meatus or posterior urethra a longish period should be allowed to pass before the catheter comes out so that repair and epithelialization may be well advanced By this means stricture formation should be rendered less likely

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CHAPTER XLVI

WOUNDS OF THE URETHRA

UP to the present urethral wounds have proved to be distinctly rare Bombs exploding on impact land mines marine torpedoes indeed most of the modern explosive weapons tend to wound from below thus theoretically more wounds of the urethra must be expected than in former wars Always serious the seriousness of urethral wounds has been heightened because they are apt to be overlooked until complications have arisen The reason for this is twofold (i) so often the case is complicated by other wounds and (ii) the wound of entry may be far from the urethra for instance in the buttock thigh or abdomen A splintered fragment of the pubis sometimes causes the urethral damage No less than 33 per cent of wounds of the deep urethra are complicated by some form of fracture of the pelvis

Fullerton stated that missiles passing transversely at the level of the lower part of the great trochanter tend to implicate the prostatic urethra whilst those passing similarly at the level of the middle of the small trochanter are more likely to involve the bulbous portion The rectum is often injured concurrently in anteroposterior wounds

A survey of collected cases makes it clear that it is the fixed portion of the penile urethra which is wounded most frequently

Small wounds are the most dangerous—Apart from accompanying injuries the complication *per se* most to be feared is urinary extravasation and this is more probable with a small buttonhole wound than with a large laceration of the perineal tissues A large wound allows ample escape and easy drainage of urine Secondary damage to the urethra from extravasation and sepsis is far more disastrous than the results of extensive primary laceration with a free drainage Aseptic urine has long been known to provide a soothing and antiseptic lotion to an open wound Moreover the bactericidal action of urea has been proved and the virtue of maggot therapy has been cited in support of this Urea and allantoin appear to be the active principles excreted by the maggots (Robinson)

The disastrous local consequences of undrained extravasated urine, whether into the pelvic cellular tissue above the deep layer of the triangular ligament or superficially into the perineum, scrotum penis abdominal wall or thigh are as familiar as the profound toxæmic symptoms it causes Extravasation is quickly followed by sepsis sloughing and gangrene all of which are aggravated by the activity of the infecting agent many cases of infection from the gas-forming organisms and the tetanus bacillus were reported during the 1914 18 war Death from shock toxæmia and ascending urinary infection were frequent

SEQUELÆ

(*a*) **Fistulæ**—These are urethro-cutaneous or urethro-rectal, and their persistence is influenced by the degree of stricture formation Many of the former may heal spontaneously, but the latter will almost invariably require the aid of surgery Reference to individual measures will be found later

(*b*) **Strictures**—The severity will vary according to the situation, the extent of the original trauma, and the degree to which extravasation was allowed to remain unrelieved at the outset The worst strictures are found in the prostato-membranous portion where urethral alignment was broken and improperly corrected in the early days of treatment

(*c*) **Persistent urinary sepsis**—Limitation of infection to the urethra and bladder is unlikely, especially where there was an accompanying and severe bone injury infection ascending to the kidneys is prone to occur, and with sepsis of this nature there is tendency to calculus formation, especially in the presence of those organisms exercising an alkalinizing action upon the urine

(*d*) **Interference with sexual function**—(i) Chordee may result from cavernous tissue fibrosis (ii) urethral fistula and stricture interfere with ejaculation and so may be responsible for sterility Sterility may also arise from occlusion of the ejaculatory ducts and interference with the function of the bladder-neck sphincter in injuries of the deep urethra (H H Young, J B Macalpine)

CLINICAL COURSE

As has been emphasized already, only too often gunshot wounds of the urethra are at first overlooked by virtue of the overwhelming seriousness of accompanying injuries It is only when retention of urine, hæmaturia, a perineal or scrotal swelling, or the escape of urine from a wound are apparent that the condition is suspected Differentiation between traumatic rupture of the urethra and bladder may at first require verification the presence of a distended bladder or interference with the passage of a catheter usually at once confirms the diagnosis A catheter passing into cellular tissue through a complete rupture might theoretically mislead, but other signs and symptoms will soon correct an error so arising When the catheter is arrested careful note is taken of the point of arrest as a guide to the precise seat of injury

The local manifestations of extravasation depend upon whether it is pelvic or subcutaneous in the former case a rectal examination may yield a doughy resistance If superficial fascial barriers are broken by the injury extravasation will not necessarily be confined to the anatomical fields so well known to the student

TREATMENT

Seeing that infection invariably adds to the gravity of the case, steps should be taken immediately to combat it in every way possible A high fluid intake is of paramount importance If the patient cannot, or will not, imbibe sufficient water, intravenous saline or glucose solution must be given Sulphonamide preparations by mouth intravenously or locally, in the powder form, are valuable

Operative treatment—As an outcome of experience in the 1914 18 war the treatment of wounds of the urethra has been fairly well stereotyped There are still a few controversial points which will be discussed later

TREATMENT OF THE WOUND—This follows the general principles laid down in this work If the wound is recent (under eighteen hours) thorough excision is carried out Damaged muscle fascia and cavernous tissue are excised Side tracks are followed up and particularly free drainage provided if urine has been extravasated into them Before approaching the urethra a metal instrument is introduced into that canal to define its precise situation and so prevent undue damage to it in the course of the wound excision

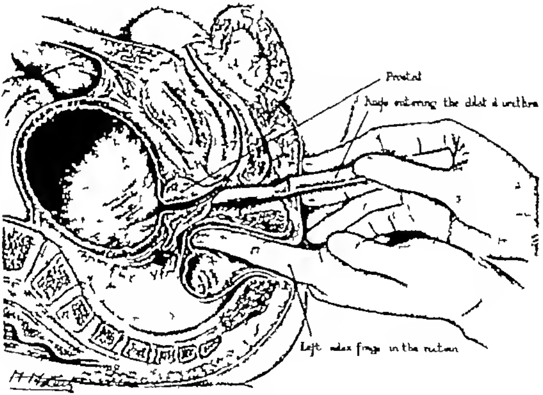


FIG 361
Cock s perineal section.

DEVIATION OF THE URINE is established by suprapubic drainage For this a Malecot tube is used and it may be inserted by the trocar-cannula method to procure a watertight joint A pre vesical drain should also be inserted

The above measures are the essentials of early treatment on arrival of the patient at a properly equipped hospital Delay in transport may have necessitated first-aid measures for the relief of the more urgent symptoms

RETENTION OF URINE is obviously the most important No doubt a catheter will first have been tried and if it passes and empties the bladder there is no great objection to tying it in If it cannot be passed and there are no facilities for intubating the bladder, aspiration with a hollow needle with the aid of an exploring syringe is the correct procedure It may be repeated when necessary, and although risking a pre-vesical abscess from leaking punctures, the danger is not great

EARLY PERINEAL EXTRAVASATION—Even at the risk of defective surgical environment incision should be made into the swollen tissue and some sort of vent provided If the technique of Cock's perineal section (Fig 364) was more widely known I think it possible that this would be adopted as a first-aid measure, for it combines drainage of the bladder with a limited drainage of the perineum through which some extravasated urine could escape

In late cases surgical intervention must be limited to débridement in the true meaning of the term—the provision of free drainage When superficial extravasation is in evidence the areas involved must be incised generously, preferably with the point of a diathermy needle or a cautery *Extravasation is one of the few conditions where irrigation of the resulting surgical wounds can be used with advantage* Subcutaneous extravasation is nearly always associated with an anaerobic infection and irrigation with Carrel's tubes and a weak solution of potassium permanganate or hydrogen peroxide is of established value Deep extravasation of urine into the pelvic cellular tissues is best drained by the method described by Macalpine, using the U-shaped incision shown in Fig 361

CONTROVERSIAL QUESTIONS

1 **Is perineal bladder drainage preferable to suprapubic?** Suprapubic bladder drainage is adopted so universally in civilian surgery that the possible advantages of the perineal alternative are inclined to be overlooked By reason of its dependent position, a perineal tube has been claimed—with justification—to give better drainage Therefore, when the patient has been wounded in the perineum it seems logical to favour this route Fullerton, from his experiences in the 1914-18 war, advocated perineal drainage I have already alluded to the possible advantage of Cock's perineal section as a first-aid measure, but its use would fail unless the posterior urethra were distended by acute retention

Another great advantage of perineal drainage is where there is subcutaneous extravasation of urine The suprapubic route to the bladder, of necessity, must open deeper and uninfected fascial planes to possible infection

Summarizing the suprapubic route has the advantage of greater familiarity to the average surgeon, but the perineal alternative should have weighty consideration, especially in late and infected cases

2 **Should attempts be made to reconstruct or repair the lacerated urethra?**

(*a*) WOUNDS OF THE ANTERIOR URETHRA—It is quite clear that no attempt at suturing should be made in late infected cases and those with extravasation of urine It is in the early cases where wound excision has been possible that this important question arises It is true that in many respects the case is similar to that of the ruptured bulbous urethra of civil practice, but regard must be given to the shock and constitutional depression from associated injuries before commencing to attempt what may prove a difficult procedure If the rupture is found to be complete and the patient is in good condition, an attempt should be made to suture the roof of the ruptured urethra. In the course of this step it will probably be necessary to open the bladder in order that a retrograde bougie can be passed to disclose the retracted ruptured end, which otherwise eludes recognition. Sutures of catgut are used to unite the ruptured roof, and they should include the underlying spongy tissue. If these sutures tend to cut out I would prefer to leave in a catheter for a week. In either case the suprapubic tube is retained for at least a fortnight and possibly longer. If the rupture is *incomplete no sutures are required* and here arises a major controversial point—should an indwelling catheter be inserted or not? Opponents of the indwelling catheter believe it aggravates stricture formation by encouraging further sepsis; supporters are convinced of its value as a splint and in preserving the lumen. I would prefer to leave in a catheter for forty-eight hours only and postpone instrumentation for a fortnight. In any case frequent bladder washes with weak acid solution, *e.g.* ½ per cent. acetic acid lotion, are essential, as the tendency to phosphate stone formation is great.

(*b*) WOUNDS OF THE PROSTATO-MEMBRANOUS URETHRA.—Where the rupture is complete and is situated in the prostato-membranous urethra, reconstruction is essential, as otherwise the altered alignment is most likely to result in the formation of an irreparable obstruction, especially if this rupture is associated with a fractured pelvis. The emplacement of a catheter to function as an internal splint must be undertaken just as soon as the general condition of the patient allows. The manœuvres to attain this objective may be difficult. The best method is to approach the rupture through an incision in the perineum as far back as possible. A fully curved metal catheter is then passed downwards from the opened bladder towards the perineum, and at the same time a rubber catheter is passed through the external urinary meatus, partly through the perineal wound and partly by working in the depth of the suprapubic wound; the rubber catheter, the tip of which is now cut off, is threaded over the end of the metal instrument. Thus it can be drawn into the bladder, where it will remain *in situ* for at least a fortnight, until, in fact, the tissues around it are condensed and adherent in the bed so formed by the catheter.

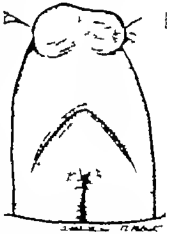


FIG. 365.
Incision for approaching a rupture of the prostato-membranous urethra.

Where the technique cannot be completed the alternative is to intubate the bladder end of the urethra and to carry a rubber catheter through and out of the perineal incision, where it will remain until a further attempt to insert a catheter along the whole course of the urethra can be made. By bringing out the catheter in the perineum the deep end of the urethra can always be identified. In the subsequent operation exposure is made through a perineal incision, comparable to the method adopted in Young's perineal prostatectomy (Fig. 65). Both ruptured ends of the urethra are under control and these, by patient dissection, are mobilized to allow approximation without tension. The ends are trimmed and held together by catgut sutures.

Whichever expedient is used to splint the ruptured urethra a favourable issue can hardly be expected unless the associated fractured pelvis is immobilized completely. When practicable a pelvic plaster cast should be employed (see Chapter LXXXII).

TREATMENT OF SEQUELÆ

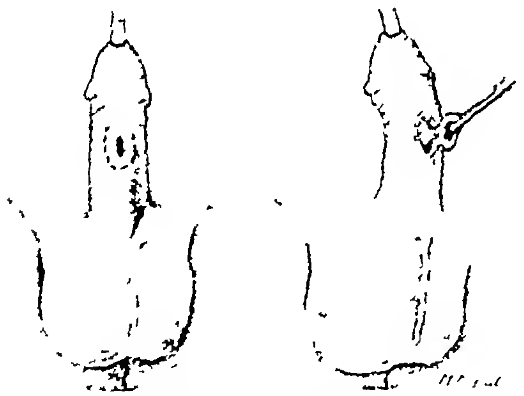
Strictures should be dealt with in obedience to the principles followed in the treatment of strictures generally Extensive and dense strictures especially in the bulbar and pre-bulbar regions, are best treated by excision, after the method of Hamilton Russell

Persistent urinary sepsis is more completely understood than formerly, and, with the aid of such powerful urinary antiseptics as mandelic acid and the sulphonamide compounds, the prospects of eradicating the infection are correspondingly improved

Stone formation, always to be suspected where infection remains obstinate, must be investigated and treated Acidity of the urine should be procured by oral and local measures Orally a protein diet and such drugs as acid sodium phosphate ammonium chloride and ammonium nitrate are ordered For local treatment bladder lavage with ½ per cent acetic acid is valuable

Sexual defects for the most part yield poorly to treatment In course of time improvement is generally noticed Faradism to the perineum may improve the tone of all the muscles in this region Chordee is seldom improved by excision of fibrous tissue

Fistulæ—The treatment of fistula is difficult Fistula following penetrating wounds may be found in any part of the urethra In every situation there is a better prospect of successful closure if suprapubic drainage is established



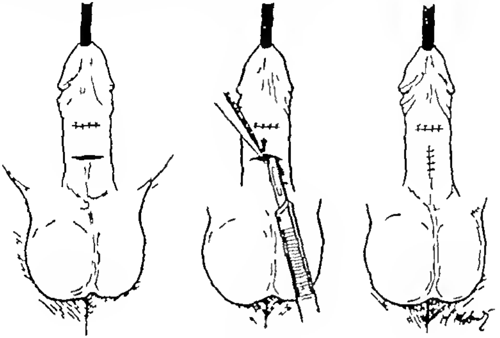
FIGS 366 and 367
Method of repairing a penile fistula

PENILE FISTULÆ

Fistulæ following war wounds are seldom in the pendulous portion of the penile urethra The majority are seen in the peno-scrotal or perineal regions Before any direct attempt is made at operative closure a stricture, if present, must be fully dilated and sepsis overcome A small fistula sometimes heals after cauterization Those resistant to the above measures may be closed

(*a*) *By excision and suture*—With a bougie *in situ* the opening is encircled (Fig 366) and the skin slightly undercut to expose the mucous membrane (Fig 367) Traction on the button of skin will render conspicuous the epithelial lined track, which is then transfixed at its attachment to the urethra The edges of the mucosa are then picked up in toothed forceps and sutured with atraumatic needles carrying 0000 catgut The ends of these sutures are left long and will be conducted out through the external meatus To effect this the long ends are threaded to a Sims' abdominal needle which is coaxed, blunt end first, out through the meatus, the ends are picked up and the needle withdrawn This step is to ensure that the knots lie within the urethral lumen and that they do not remain to aggravate sepsis The skin is then sutured In one case where a number of previous attempts at closure had failed, I sutured the skin transversely (Fig 368, A) after it had been undercut considerably (Fig 368, B) to ease tension To further the relief of tension, another transverse incision was made three quarters of an inch proximally and undercut under its distal edge (Fig 368, A) Tension caused this incision to become almost circular, and by suturing the latter longitudinally (Fig 368, C) relaxation of the bridge of skin ensued and healing was rapid

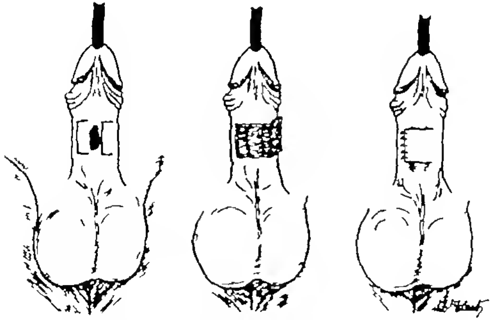
(*b*) *By closure with flaps (autoplasty)*—Here the Guyon method is adopted, for, by its aid, a considerable gap in the floor may be closed Two quadrilateral flaps are constructed after the edges of the fistula have been trimmed (Fig 369, A) On one side of the gap the margin nearest the urethra is left attached and is the hinge upon which this flap swings as it is folded over to form the new floor (Fig 369, B) The other flap remains attached laterally and is not folded, but merely placed and sutured over its partner (Fig. 369 C). Each flap is sutured carefully in place and especial care is observed that the short edges of the flaps are attached in precise apposition with the mucosa at



A B C

Fig. 368

[illegible] method of treating a recurrent penile fistula



A B C

Fig. 369

Guyon's method of closing a fistula by flaps.

each end of the fistula. The flaps should be as thick as possible to preserve their vascularity as well as to give a good hold for the stitches. This method should provide a wide urethral floor and so resist later stricture formation.

FISTULÆ OF THE POSTERIOR URETHRA

(*a*) *Urethro-cutaneous*—In these cases, which present in the perineum in addition, massive formation of fibrous tissue is often encountered and adds to the difficulties A curved transverse incision from one tuber ischii to the other is made anterior to the fistula concave posteriorly If a bougie passes easily into the bladder a second incision concave anteriorly, is made behind the fistula, which is thus encircled The fibrous tissue and fistula are removed *en masse* to the urethra, the position of which is defined by the inlying bougie The cavity so left is packed with gauze Secondary suture will often hasten healing Baths should be taken as soon as possible Late catheterization may be necessary to assist closure If there is a stricture, possibly even loss of continuity, there is no alternative but to expose the urethra proximal and distal to it upon bougies passed from without and retrogradely Only by patient dissection and undercutting for mobilization can the ends be approximated where there has been complete division Where partial, the stricture may be incised or, better, excised When the posterior end is exposed help in freeing and mobilization may be gained by passing a Young's tractor which, by depressing the bladder floor, brings the structures for revision to a more superficial plane If possible, sutures should be placed between the edges of the anterior wall and a catheter is then passed up through the penis and into the bladder With this as a scaffolding and guide, sutures are passed to unite the edges of the lateral wall The wound is then packed and drained

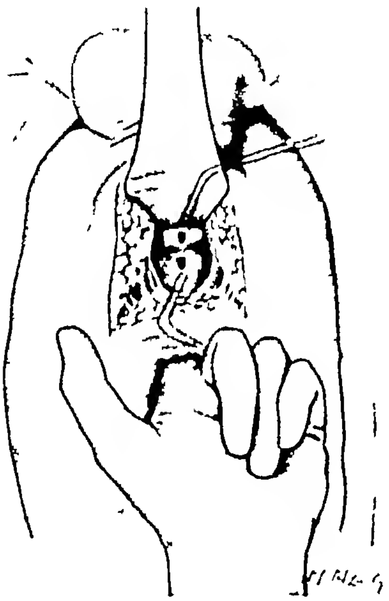


FIG 370

Recto urethral fistula The rectum has been separated from the deep urethra and the resulting opening in both structures is about to be closed

Where suturing is found to be impossible, on account of fibrosis and difficulties of approach there is little to do other than to retain continuity by an indwelling catheter in the hope that the tissue around will so mould itself to the required shape and that the lumen retained by the catheter will ultimately be epithelialized into a new urethra Frequent dilatations will be required in the first year, but ultimately a urethra so formed may remain uncontracted for months

(*b*) *Urethro rectal fistula*—Two different methods are used for the closure of these (i) by individual closure of each opening by a transperineal route (ii) by rectal mobilization, the Young Stone technique

(i) *By individual closure*—A wide transverse inter-ischial incision is made, and, with a finger in the rectum as a guide, this is deepened until the region of the fistula is encountered A large bougie is then passed into the bladder through the urethra, and, with this as an additional guide, the urethra and the rectum are separated by dissection In this separation the track of the fistula will be defined in its bed of dense fibrous tissue In the course of this separation abscesses may be opened and a foreign body removed The fistula track is divided as near as possible to the urethra and rectum respectively, and removed (Fig 370) To complete the operation, either the openings in the rectum and urethra may be closed by catgut sutures when this is possible, or the cavity is simply packed thus relying on spontaneous closure The perineal incision is brought together with a few interrupted silkworm gut sutures

(ii) *The Young Stone technique* comprises steps similar to those employed in the Whitehead operation for hæmorrhoids The anocutaneous margin is followed by an encircling incision which is deepened to the interval between the anal wall and the external sphincter Still pursuing this plane the deepening is advanced and while so doing the anal canal and rectum are delivered The external sphincter may require division in the mid line anteriorly to assist in separation of the anchoring fibrous tissue, so allowing descent of the bowel In this way the affected area of the bowel is delivered and excised, the healthy bowel is stitched to the anocutaneous margin and packing is placed in what space remains in the cellular tissue between the anus and urethra Fuller details of this operation may be obtained from the excellently illustrated articles of H H Young in his textbook

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CHAPTER XLVII

WOUNDS OF THE SCROTUM, TESTICLES AND PENIS

THE 1914-18 war proved that wounds of the external genitalia were comparatively common and that they provided their own special problems (Delorme, Leguen). It is not that these wounds are in themselves fatal; they are not, although unfortunately the total mortality is considerable because of associated damage to neighbouring structures, notably the pelvis, pelvic viscera, the perineum and thigh; their sequelæ, however, may often militate against the patient's mental well-being.

WOUNDS OF THE SCROTUM AND TESTICLES

Wounds of the scrotum and testis are, for the most part, lacerated wounds with loss of tissue.

The scrotum possesses great regenerative powers. Its wounds are relatively trivial and the loss of tissue is usually more apparent than real. After scrotal wounds it is remarkable with what ease a satisfactory scrotum can be refashioned from what may appear to be totally inadequate fragments. The new scrotum can be constructed from skin flaps taken either from the medial aspect of the thighs or from the abdominal wall. The testes usually need to be freed from fibrous scar tissue so that they may be placed in the re-formed scrotum. Even when the scrotum is destroyed completely (Fig. 371) it is not a difficult matter to provide a covering for the testicles at a later date.

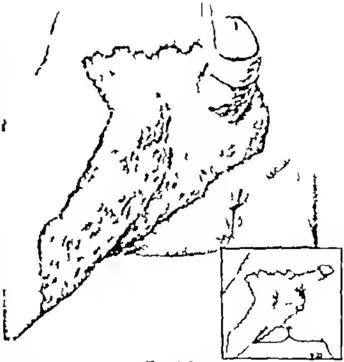

FIG. 371

An extensive granulating wound. The scrotum has been destroyed and there is skin loss of the thigh. The penis is stripped but otherwise intact and the testicles are uninjured; they are buried in granulations. *Inset*—The shaft of the penis placed in a skin tunnel.

The testicle—It is not uncommon for the testis, enclosed in its tunica vaginalis, to herniate through the scrotal wound (compound dislocation of the testis) and if the tunica is torn the testis itself protrudes Lacerated and contused wounds of the testicle itself are liable to result in hernia or fungus with extrusion of the seminiferous tubules (Fig 372) With an incised wound of the tunica albuginea it does not occur in the absence of inflammation intratesticular hæmorrhage or other cause of increased tension (Cunling)

FIG 372

Perforating wound of the testicle Through the larger wound of exit testicular parenchyma has herniated (W O Coll, R C S, 1196) (*Gordon - Taylor British Journal of Urology*)

Contusions of the testis without rupture of its tunica albuginea cause intratesticular hæmorrhage in varying degree and if severe result in disintegration of the tubules with in extreme cases the development of what has been termed an intratesticular hæmatocele Severe contusions are associated with scrotal hæmatomata which may reach a great size and are liable to cause gangrene of the overlying skin Contusions with rupture of the tunica albuginea result in hæmatocele formation sometimes bursting the testis so that the seminiferous tubules are extruded into the cavity of the tunica vaginalis

Injury to the spermatic cord is chiefly of importance in that the blood supply of the testis may be destroyed Destruction of the internal spermatic artery often leads to atrophy as a rule without gangrene of the testis this latter event is usual if the veins also are interrupted (Cedermark) and it is more likely in the presence of sepsis Division and retraction of the cord has resulted in enormous hæmatomata of the retroperitoneal tissues, but this accident is a rarity

Treatment of testicular injuries—CONTUSIONS—Scrotal hæmatomata are treated by early evacuation of blood and blood clot This will also afford an opportunity to examine the testicle The tension of an intratesticular hæmorrhage must be relieved by multiple punctures of the tunica albuginea if there is to be any hope that atrophy will be avoided

WOUNDS—The records of the 1914-18 war show that conservative treatment is advisable for all wounds of the external genitalia, and for that reason more discretion should be exercised in the ablation of doubtfully viable tissues than in other situations Should the testis be dislocated through a scrotal wound it must be cleansed and returned This necessitates the division of the encircling collar of scrotal tissues which often prevents its return and tends to strangle the testis (Delorme)

The following examples contrast the differing treatment of clean-cut wounds and of lacerated projectile wounds

Incised wounds—The wound is a simple incision and has wounded the testis which may, or may not have prolapsed through the scrotal wound Unless the testis is injured grossly it is unlikely that any protrusion of the seminiferous tubules will have taken place

The wound is inspected and cleansed then the wound of the testis is closed by means of interrupted catgut sutures which may be of the Lembert type If the testis has prolapsed the tunica vaginalis or scrotum, or both, may form a tight collar requiring incision before reduction can be effected After reduction a small rubber drain is led from the surface into the cavity of the tunica vaginalis which is not closed and the scrotal wound is sutured in two layers The first suture is of No 0 catgut and draws together the dartos layer the second is a fine non absorbable suture of the skin Interrupted sutures are the better if infection is feared but a continuous suture secures more accurate adaptation of the margins After operation efficient support must be provided for the scrotum (Fig 373)

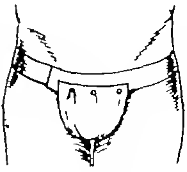

Fig 373
The Jock strap

Grossly lacerated projectile wounds—Conservatism is aimed at but the question of orchidectomy often needs careful consideration The toilet of the wound is effected by thoroughly scrubbing with soap and water by exploration for foreign bodies removal of devitalized tissue and the excision of the wound margins but conserving what scrotum is possible If survival of the testis or of part thereof is deemed probable it is replaced in the scrotum All sutures are avoided and the wound is left widely open If doubt exists as to the viability of the testis it is left exposed if necessary outside the wound so that observation can be maintained If the testis is hopelessly injured (Fig 374) or if its blood supply has been destroyed the cord is ligatured and the testis or its remains removed The wound may be treated with sulphapyridine and is provided with an oily dressing either vaselined gauze paraffin and flavine (1 2 000) or fish liver oil (Odelberg) can be used Free drainage is supplied and support is afforded to the parts

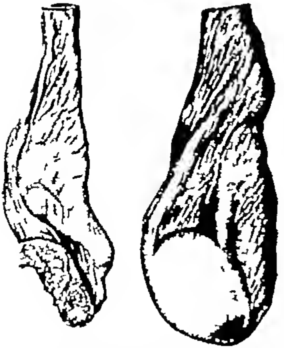

Fig 374
Testicles from a man who died of abdominal wounds The chief part of the right testicle has been shot away on the left side there is a hæmatoma of the spermatic cord (W O Coll, R C.S., 1195.) (*Gordon-Taylor British Journal of Urology*)

Delayed or reparative treatment—When the wounds are soundly healed steps are taken to remedy deformity and as far as possible to repair damage and restore the parts In general this entails the excision of scars and the freeing of adhesions with probably the addition of various plastic procedures

Atrophy is the most frequent result of wounds of the testis (Otis) It may be due to extrusion of the seminiferous tubules but is more usually the effect of fibrosis which either succeeds inflammation loss of blood supply or is the result of the organization of effused blood (Fig 375) Sterility, of course, follows the loss of both testes, but may be due to interruption of the excretory canals Impotence is not necessarily a sequel of castration, although desire gradually lessens and potency may disappear Neuralgia testis is another sequel of wounds and not infrequently is associated with atrophy An exquisitely tender gland may require orchidectomy

Fig 375

Section of a testis, showing the effects of an intratesticular hæmorrhage—marked fibrosis, cellular infiltration and degeneration

WOUNDS OF THE PENIS

The damage inflicted varies from denudation of the skin and partial laceration of the corpora cavernosa to amputation, or even complete destruction Hæmorrhage rather surprisingly is often less than might be expected and except in clean incisions, is often slight It is unusual to find a wound of the penis which is not complicated by an injury to the urethra

Treatment—It is important that urine should not come into contact with the wound and suprapubic cystostomy best achieves this end As much as possible of the penis should always be saved It is a tough and viable structure and in the toilet the object of the surgeon is not to reach undamaged areas but to excise only definitely lifeless tissue The remnants of the organ are then wrapped in an oily dressing In some cases it is wise to splint what remains of the cavernous tissue with finger splints, which are suspended from a cage across the thighs This prevents adhesions and minimizes deformity

The reparative surgery of the penis is chiefly subordinate to that of the urethral injury either fistula or stricture, one of which is almost invariably present Although severe wounds often result in actual loss of substance, even in almost complete transverse lesions of the corpora, union has been obtained by secondary suture therefore at times it may be found expedient to begin the repair when a healthy granulating stage has been reached Moreover, Bogoras in a patient who had lost the pendulous urethra, succeeded in reconstituting a functional organ by transplanting a costal cartilage provided with skin covering to the remaining erectile tissue of the root of the penis The urethra was then reconstructed, the whole with eminently satisfactory results However, in the main, plastic operations have been limited to release of the penile remnant and the provision of skin grafts to clothe it a freed and bare penis may be placed in a tunnel beneath the skin of the thigh or abdomen and later released with its new covering (Fig 371 inset)

The almost completely severed penis can sometimes survive in a surprising manner and even if the root of the penis is destroyed the pendulous portion should be given every opportunity of survival for Young has shown that wide perineal excision does not destroy the vitality of the distal penis

It would seem from Young's experience and from the exploit of Bogoras that advances in the reparative surgery of the penis are probable This is an important consideration for psychic changes usually follow the loss of the penis Indeed several observers have noted that the loss of both testes in spite of the associated endocrine deficiency has actually less effect than destruction of the penis alone

Experience has shown that satisfactory coitus is seldom possible after a severe injury to the penis Scarring adhesions deformity and loss of substance each and all account for this

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SURGERY OF MODERN WARFARE